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ABSTRACT

A study on the intellectual consequences of science teaching in the classroom is reported in this dissertation to illustrate the importance of the views of science emerging in instruction and to produce an analytical scheme for detecting students' ability to judge knowledge claims rationally and independently of their teachers. Instrumentalism and realism were chosen as two labels of the views of science, and intellectual independence and dependence were referred to as provisions made by instances of teaching. Features were logically derived from the two views and from the philosophical analysis of teaching and epistemology to serve as the items of the scheme. Revision was made to make each item correspond with classroom speech and to increase reliability. Empirical data were collected by analyzing 14 ninth- and tenth-grade lessons and interviewing teachers. Three independent judges were requested to determine the scheme reliability. The author concluded that the significance of investigating classroom discourse for the provision of the view of science and intellectual dependence and independence was ascertained in the theoretical component of this study. The analytical scheme could be used reliably for provision assessment. Further applications of the scheme to research and teacher supervision were recommended. Included are the lessons used, interview transcriptions, scheme items, and judgements. (CC)

THE PROVISION MADE FOR SELECTED INTELLECTUAL CONSEQUENCES BY SCIENCE TEACHING: DERIVATION AND APPLICATION OF AN ANALYTICAL SCHEME

by

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Doctor of Philosophy in the

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THE PROVISION MADE FOR SELECTED INTELLECTUAL CONSEQUENCES BY SCIENCE TEACHING: DERIVATION AND APPLICATION OF AN ANALYTICAL SCHEME

(Abstract)

This study is based on two purposes: first, to demonstrate the significance of certain intellectual consequences of science teaching, and second, to produce an analytical scheme for detecting whether or not provision is made for those consequences in classroom discourse. The potential consequences of concern to the investigator and detected by the scheme are (1) the view of science provided (Realism or Instrumentalism, after Nagel's use of the terms), and (2) the provision made (or not made) for pupils to assess knowledge claims rationally and independently of their teacher (Intellectual Independence and Intellectual Dependence, respectively, as defined and elaborated by the investigator).

The significance of the view of science provided in teaching is demonstrated by considering two ways of viewing explanation: the Deductive Paradigm, as described by Hempel, and the System Paradigm, as described by Meehan. The paradigms are examined to reveal how each implies a different view of science (as <u>the</u> way to explain or as <u>a</u> way to explain), and to show that pupils can derive a different view of science itself, and a different view of the world, from each.

The significance of Intellectual Independence and Intellectual Dependence is demonstrated through an examination of Scheffler's treatment of epistemology and through features of philosophical analysis of the concepts "teaching" and "indoctrination." It is shown that the fashion in which knowledge claims are supported in teaching logically governs the degree to which pupils can judge the truth of claims independently of a teacher.

No scheme available for analyzing classroom interaction is designed to detect the provision made for these intellectual consequences. Thus the investigator has concentrated on developing such a scheme, rather than attempting to measure actual consequences to pupils. The latter approach was not chosen because measuring devices are not available to detect these consequences, and also because inferences about the correlation between teaching and pupil achievement depend on simultaneous analysis of what, in fact, was provided by the teaching to which the pupils were exposed. Development of an analytical scheme is a prerequisite to any such measurement of pupil achievement, then.

The scheme consists of two categories. Category 1 contains items for detecting the view of science provided for by teaching (Realism or Instrumentalism), and Category 2 contains items for detecting provision for Intellectual Independence or Intellectual Dependence. Items in Category 1 are derived logically from Nagel's account of Realism and Instrumentalism. Basically, these items follow from different positions about the logical status of theories and the ontological status of "scientific entities" (ions, charges, genes, etc.). Items in Category 2 incorporate epistemological features of teaching and features resulting from analyzing the concepts "teaching" and "indoctrinating."

The theoretically derived scheme is then revised on the basis of a preliminary analysis of two transcribed science lessons (each accompanied by a transcribed interview with the teacher, used to determine the context of the lesson). It is shown that this revised version of the scheme can be used with reasonable reliability by having three independent judges use it to analyze a third transcribed lesson (accompanied by its transcribed interview). The result: 82.3% overall agreement. Since there is no rigorous way to determine the significance of this percentage of agreement, an estimate of inter-judge reliability is made by using the contingency coefficient "C" for nominal data. This estimate suggests an inter-judge reliability for the scheme which is statistically significant at the .01 level of confidence.

A fourth transcribed lesson (accompanied by its transcribed interview) is analyzed by the investigator, to demonstrate features of the scheme which do not emerge clearly from the analysis by the three independent judges. The complete lesson and interview transcriptions, together with all judgments, are appended to the document.

Finally, implications are drawn for further research and for the use of the scheme in the supervision of science teaching.

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CHAPTER I

INTRODUCTION

This study is an investigation of selected characteristics of science teaching: the _potential_ of science lessons for influencing a pupil's understanding of (a) different views of the nature of science, and (b) the substantiation of knowledge claims within science. A rationale is developed in order to demonstrate the importance of investigating these characteristics of science teaching. An analytical scheme is derived from theoretical considerations, and is applied to samples of science classroom discourse, in order to demonstrate that different treatments of these two characteristics of science teaching can be detected. The reliability of the scheme is tested as well, by three independent judges.

The Problem

Two approaches seem to characterize the study of teaching: (1) analysis of teaching acts and pupil responses in classroom discourse (against stated criteria for describing or evaluating teaching), and (2) measurement of pupil achievement (_from_ which teaching "effectiveness" is inferred, or _with_ which it is correlated). Both approaches have been used in science education research. But, given the "state of the art" at this time, the results of both approaches are not very helpful for this investigation.

The first approach (analysis of teaching acts and pupil

responses) is the one used here. A particular perspective is being used, on the basis of systematic theoretical considerations, to analyze science classroom discourse. As documented in Chapter II, many classroom observation schemes have been developed and tested; these offer a variety of perspectives for analyzing teaching acts and pupil responses. But none of these schemes (the result of which is labelled here as representing the "observation paradigm" of research on teaching) is useful to analyze science teaching for the two characteristics important to this study. No studies within the "observation paradigm" offer perspectives that allow for detection of the potential consequences to pupils of these characteristics. Thus it is necessary to develop a new scheme.

The second approach, represented here as the "achievement paradigm," cannot address the concerns of this study for two reasons. First, necessary measuring devices would have to be based upon conceptualization of the consequences to pupils of different treatments of epistemology and the nature of science. Such measuring devices have not been developed. Second, the use of achievement measures as indicators of "effective" teaching demands evidence that measured consequences are indeed consequences of, or correlations to, teaching. That evidence is obtainable only from a simultaneous analysis of science teaching, using a device that offers similar conceptualizations. And, as asserted above, the "observation paradigm" has generated no such device before this time.

So, the major problem for this study is that neither the "observation paradigm" nor the "achievement paradigm" currently permits

investigation into certain characteristics of science teaching which the investigator judges important for reasons demonstrated below.

There is a corollary to this problem. One cannot examine actual instances of teaching to see what provisions are being made by these characteristics until there _is_ a reliable device for doing so.

Purposes of the Study

The purpose of the study is twofold: first, to demonstrate the importance of certain intellectual consequences of science teaching which cannot be investigated by available research approaches and, second, to produce an analytical scheme for detecting reliably whether or not _provision is made_ for these consequences in classroom discourse. Three specific kinds of intellectual consequences are examined.

Because science teaching eventuates in knowledge claims, one potential consequence for pupils is directly related to the explicit or implicit information communicated by the teacher about ways to judge the credibility of such claims. The epistemological conditions necessary for making judgments of this sort suggest that this aspect of science teaching can be fruitfully analyzed using a perspective derived from epistemology.

But implicit or explicit information about ways to judge knowledge claims is only part of what pupils can derive from science teaching. In science, knowledge claims are concerned with the physical world, so pupils can derive ways of viewing the world, and also views of the capacity of science for explaining or describing the world. Alternative views of the nature of science incorporate views of its history

and development, and of the logical status of theories and constructs employed in the discipline. In this study, features of such views are conceptually organized within a framework derived from the philosophy of science. Thus, portions of teaching can be characterized according to potential consequences provided by the view of science given in classroom discourse.

The above two kinds of consequences relate to views pupils can derive from science teaching. The third kind of consequence concerns ways in which classroom discourse can influence the adopting of views and the judging of claims to truth. There is, for example, a clear distinction between teaching which allows pupils to adopt views autonomously and rationally, and teaching which leaves pupils dependent upon their teacher for the selection and adoption of particular views. Similarly, one can distinguish between teaching which allows pupils to judge the truth of knowledge claims independently, and teaching which leaves pupils dependent upon their teacher for judgments of truth. Distinctions from the philosophical analysis of teaching will be used to examine these provisions in science lessons.

So, the theoretical component of this study uses philosophical perspectives to demonstrate the importance of these three kinds of intellectual consequences. The perspectives are also used to produce the analytical scheme. But the full purpose of the study would not be achieved without an empirical component which shows that the scheme can be used successfully and reliably. The last portion of the study offers this evidence.

Significance of the Study

This study is significant, in the investigator's judgment, because the potential consequences of teaching investigated here are of fundamental importance in science education. The following sections show briefly the nature and significance of these consequences, and illustrate some aspects of the method of analysis used in the study.[1]

A Sample of the Basis of Consequences for Pupils

An excerpt from a current science textbook is analyzed in this section, to show the basis for potential consequences to pupils inherent in a series of statements whose intention is to teach. The meaning of the passage is interpreted by attaching the meaning of "ordinary language" to the words "actually" and "contains."

Of course, this approach necessarily ignores other interpretations of the passage that might result from knowledge of the context in which pupils read it (given what has preceded it in the textbook and/or teaching). But the sample analysis merely serves to illustrate the basis of potential consequences in science instruction. Quite clearly, one must determine whether a passage of instruction is conveyed in an "ordinary language," or some other context, when analyzing science lessons in this study. Chapter VI contains discussion and examples of the interview techniques used to determine the context of lessons for the purpose of establishing the scheme's reliability.

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[1]Arguments appearing here are amplified later, since the analytical scheme and its rationale are developed together in this study.

The excerpt from the text asserts:

> Actually, any piece of matter large enough to be visible contains a large amount of electrical charge, both positive and negative. If the amount of positive charge is equal to the amount of negative charge, this piece of matter will appear to have no charge at all, so we can say that the effects of the positive and negative charges simply cancel each other when they are added together.[1]

Assuming an "ordinary language" context, the explicit and implicit basis of consequences for pupils in this passage can be unfolded analytically from the single assertion that all visible matter contains charges, as follows. The language of the assertion implies that "actually" the world "contains" these entities called "charges." Thus the entities "exist" in the "ordinary language" sense. It follows that science has, in this case, correctly determined what is "actually" out there, in the world.

The implication that science has the potential for producing accurate descriptions of this type carries implicit information about the processes of science. From a logical standpoint, declaring this assertion about charges (and implying it to be true) requires that alternative descriptions be considered false. Thus, previous efforts at explaining electrical phenomena (e.g., those which employ notions of electrical fluids) are incorrect and, further, we need expect no alternative correct descriptions in the future. On this view, science has successfully and finally completed its inquiries into these states of affairs.

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[1] Harvard Project Physics, 4: Light and Electromagnetism. Authorized Interim Version. (Toronto: Holt, Rinehart and Winston, 1968), p. 39.

Sample Consequences for Pupils

This analysis has shown that a particular view of science is implied by the text excerpt, if it is read in an "ordinary language" context. Simply put, the view is that science aims to provide true and final descriptions of the world. (Whether the pupils would actually interpret the passage in that way is an important issue, of course. But they could so interpret it.) An analysis of this view reveals potential consequences for pupils who have prolonged and sustained exposure to such a presentation of science.

Quite clearly, the finality of the aims of scientific inquiry implied by this view logically suggests that what is currently provided as scientific information in classrooms (in a manner similar to that of the text excerpt) is accurate description of the world. And this view of scientific information might well lead pupils to a stance in which openness to novel theories in the discipline is preempted. Indeed, this sort of view suggests that science is unlimited in its capacity for accurately describing and explaining phenomena, so there is no opportunity for such a view to accommodate understandings of the limitations of science.

Since these consequences speak to fundamental understandings of the nature of science, the investigator contends that they are highly significant in themselves. But views of science can influence personal ways of looking at the world. So consequences such as those derived above can have added significance to pupils. For instance, the notion that science has unlimited capability for explaining phenomena, coupled

with the view that such explanations are accurate descriptions of the world, may present serious conflicts for pupils who prefer to explain aspects of their experiences in ways quite distinct from science. Explanations of this sort might involve animism and teleology, as featured in magical or theistic explanations. Moreover, presenting science as <u>the</u> correct way to explain events logically disallows an unbiased choice for pupils about ways in which they might explain experience and thereby render it intelligible.

These potential consequences are all derived by analyzing the view of science provided in the text excerpt. Other potential consequences can be derived from the ways in which knowledge claims are supported.

For instance, in the cited passage, no mention is made of evidence or argument which supports the assertion about charges, and no reference is made to evidence and argument provided earlier. (This is, of course, a major part of the "context problem." Pupils are <u>expected</u> to read the statements in the context provided earlier.) If no evidence and argument are provided, or if pupils fail to read the statements in the context of evidence given previously, then this excerpt can be seen as leaving pupils unfamiliar with the manner in which claims are made and supported. The result: pupils are not provided the basis for understanding the nature of the intellectual inquiry that characterizes the discipline.

But there are other possible consequences of science teaching which fails to provide pupils with means for judging the truth of knowledge claims, or else does not remind them of context at appropriate

times. Briefly, such teaching can leave pupils dependent upon the teacher's (or textbook's) authority for the truth of claims, thus leaving pupils unable to judge the truth of claims for themselves. The investigator finds this consequence to be of fundamental importance, for the ability to judge the truth of claims is basic in all intellectual endeavors.

Summary of Significance

The preceding two sections have revealed the capacity of science teaching to provide for intellectual consequences of fundamental importance to pupils. These are related to views of the nature of science, and to ways of judging the truth of knowledge claims. But, as demonstrated in Chapter II, there are currently no means for investigating this capacity. So the study is significant in two ways: first it shows the importance of examining specific potential consequences of classroom discourse and, second, it provides a device for investigating these.

Definitions

In this study, the investigator intends that certain terms (phrases, actually) be understood in a specific way. There are five such phrases, and the stipulated meaning for them is specified in the following three sections.

The Provision Made by Science Teaching

For this study, the *provision made* by science teaching is defined as the *potential consequence for pupils* of the explicit and implicit messages of science classroom discourse. (This approach to the

study of teaching deliberately does not focus on what pupils actually learn, for reasons explained earlier.) The study concentrates on two kinds of provisions made by science teaching: first, views of the nature of science, and second, ways to judge the truth of knowledge claims.

It is important to distinguish at the outset between the provision made by an instance of science teaching, and the provision implied by the fact that science (a discipline based on certain principles) is what is being taught. The principle of falsifiability provides an example. According to this principle, all scientific theories and explanations are falsifiable, by definition. But one cannot say, just because theories or explanations are the subject of classroom discourse, that provision is being made for pupils to understand the principle of falsifiability. (Indeed, it is conceivable that certain presentations of scientific theories can convey quite the opposite view: that theories in science are final and immutable.) So, disregarding other provisions made for pupils to understand the principle of falsifiability, it is clear that discussion of a theory does not, of itself, make provision for pupils to understand that theories are falsifiable. And so it is for any other logical principle of the discipline of science itself.

Realist and Instrumentalist Views of Science

The study concentrates on two kinds of provision made by science teaching; the first requires characterization of views of the nature of science. The two contrasting views of science chosen for that purpose are labelled "Instrumentalism" and "Realism," after Nagel's use of the

terms.[1] Complete exposition of features of these views appears later, following an analysis of Nagel's account of the status of theories and constructs. For now, the positions can be distinguished as follows. For Realism, theories are statements which are either true or false, and the "scientific objects,"[2] such as genes, electrons, atoms, etc., that appear in theoretical statements are depicted as having a physical existence. For Instrumentalism, theories are conceptual devices, being neither true nor false, and "scientific objects" are theoretical entities having no physical existence.

The selection of these two views and their labels invites two difficulties. First, to force philosophical positions into one or the other alternative is to risk doing violence to some distinguishing features of the positions--a limitation of this study to be discussed later in this chapter. Second, although the investigator's terms coincide with Nagel's, the analysis needed to relate features of his two positions to potential consequences for pupils requires some modification of Nagel's treatment. This is unfortunate, for Nagel's treatment is systematic and coherent, yielding distinctions which might be thought to be consistent with those of other systematic philosophical treatments

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[1] Ernest Nagel, <u>The Structure of Science: Problems in the Logic of Scientific Explanation</u> (New York: Harcourt, Brace and World, Inc., 1961).

[2] The phrase "scientific objects" is Nagel's. His and the current use coincide in that the phrase refers to unobservable but named entities whether they are postulated or real. By employing this neutral phrase, one avoids the awkwardness of talking about postulated entities that exist, or about physical entities that are conceptual, when contrasting Realism and Instrumentalism.

as well. (His "realism," for instance, might well be thought to be congruent with "metaphysical realism.") Yet Nagel's distinctions, as they stand, are not entirely useful for the purposes of this study. Rather than invent new terms, and thus sacrifice the systematic basis Nagel provides, the investigator has chosen to signal the use of the modified position by capitalizing the first letter of "Realism" (also "Realist") and "Instrumentalism" (also "Instrumentalist") throughout the study.

Thus defined, the terms "Realism" and "Instrumentalism" (with first letter capitalized) refer to the investigator's modified version of Nagel's positions (of the same name) regarding views of the nature of science.

Intellectual Independence and Intellectual Dependence

The other kind of provision made by science teaching, on which this study concentrates, is the provision for substantiating knowledge claims in science. Instances of science teaching will be characterized according to whether or not they make provision for pupils' Intellectual Independence in substantiating knowledge claims.

To make provision for Intellectual Independence is to make provision for pupils to have the resources necessary for judging the truth of knowledge claims independently of others. Thus, an individual judging the truth of a claim on the basis of all assumptions, evidence and arguments necessary for that judgment is exercising Intellectual Independence. (Similar conditions obtain for Intellectual Independence in the adoption or rejection of values, views of science, and views of the world.) If, for lack of one or more of the conditions necessary for

Intellectual Independence, an individual is obliged to rely upon someone else's authority, then it is stipulated that the first individual is intellectually <u>dependent</u> upon the second.

"The provision made by science teaching" has been defined deliberately to exclude actual outcomes of teaching, and thereby to avoid mention of anything implying what pupils have learned. Yet the words "Intellectual Independence" and "Intellectual Dependence" suggest learnings quite plainly. Hence it is necessary to think of these two conditions as <u>potential</u> intellectual consequences, and as characteristics of instances of teaching rather than of what pupils have learned. An appropriate characterization of a science lesson might be, "This teaching makes provision for Intellectual Dependence."

Thus defined, Intellectual Independence and Intellectual Dependence (with the first letters capitalized throughout the study) refer to provision made by instances of teaching, because they represent <u>potential</u> intellectual consequences for pupils.

Limitations of the Study

This study is limited by the investigator's attention only to provisions made by science teaching (to the exclusion of outcomes), and by the selection of only two conceptual perspectives used to detect these provisions. These are limitations of the theoretical component of the study, and are discussed here. Limitations of the empirical component of the study, in which the scheme is found reliable, are discussed in the final chapter.

Only Limited Claims

The focus upon provisions made by teaching, rather than outcomes (or a combination of provisions and outcomes), is necessary in this study because of the state of the art of research on teaching, as noted earlier. As a result, the claims that can be substantiated in this study are limited to claims about the meanings potentially conveyed by teaching, and their logical implications as potential consequences for pupils. This is a limitation of any "observation paradigm" study which attempts to develop a new conceptual perspective on teaching. Still, it is a limitation, since no claims can be made about what pupils learn as a consequence of teaching.

The Selected Characterizations of Teaching

The second limitation of this study stems from the investigator's decision to use alternative characterizations in the analytical scheme. This decision is defensible in the case of Intellectual Independence and Intellectual Dependence for these are alternatives by definition. But the use of two characterizations of views of the nature of science seems to suggest that there are only two. This is not defensible, of course, and is certainly not the investigator's purpose in using the alternati ' , Realism and Instrumentalism.

The investigator's purpose in using these positions lies in the forcefulness and ease with which one can subsequently point to the potential impact of teaching which implies different views of the nature of science. Quite pragmatically, then, to support the claim that different views of science can be detected in teaching, and to show that

such differences provide for quite distinct and significant consequences, one need work with only two alternative views. Views such as idealism, pragmatism, contextualism and nominalism are not amenable to placement in distinctly opposite camps. So, confining characterizations of science teaching to either Realist or Instrumentalist admittedly ignores features of other views that might be present, but for the reason specified.

Of course, the process of stipulating and using alternatives is not without parallel in scalar research. Tomkins' "Polarity Scale," for instance, requires responses to one or the other of quite opposite items.[1] Furthermore, it is worth noting that the current study constitutes quite embryonic investigation of this sort into science teaching. Should the present use of alternatives prove insufficiently discriminating, the study lays groundwork for later and better differentiation. Such finer distinctions seem unwarranted at this stage, for the study shows that the current distinctions can be used to characterize science teaching according to the intellectual consequences selected for the study. Thus, despite the self-imposed limitations of the investigation, the stipulated alternatives can be used profitably for analyzing science lessons.

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[1] The "Polarity Scale" (New York: Springer Publishing Company Inc., 1954) measures affective posture according to left-wing or right-wing responses on items. A rationale for the polarization appears in Affect, Cognition, and Personality, ed. by Sylvan S. Tomkins and Carroll Izard (New York: Springer Publishing Company, Inc., 1965), in the chapter "Affect and the Psychology of Knowledge," pp. 72-97.

Overview of the Study

Arguments in this study are designed to accomplish three tasks. First, in an analysis of available studies, arguments support the investigator's contention that current research on science teaching cannot be used to investigate characteristics of teaching which are the concern of this study. Second, in a theoretical component, arguments demonstrate the importance of these characteristics and develop an analytical scheme for investigating them. Third, in an empirical component, arguments refine the analytical scheme and show that it can be used reliably. These parts of the study are described below. Since current research is analyzed in Chapter II, little mention is made of it here. The theoretical and empirical components, though, are described more fully.

Analysis of Current Research

In Chapter II, a model is used to analyze features of the "observation paradigm" and "achievement paradigm" of research on teaching. Both paradigms are found to lack research devices that might be of use to this study. Furthermore, studies representing the "achievement paradigm" have experimental designs unsuited to investigating potential consequences such as those examined by this study.

A separate section is devoted to studies whose philosophical perspectives are similar, in part, to those developed in this study. These studies are unusual to the "observation paradigm." In addition, some provide evidence that science instruction can be analyzed fruitfully by using philosophical perspectives.

<u>The Theoretical Component</u>

The theoretical component is presented in two parts, each part eventually yielding one category of the analytical scheme. The first category of the scheme contains items for detecting the view of science provided in teaching: Realism or Instrumentalism. Items of the second category detect provisions for Intellectual Independence or Intellectual Dependence within science teaching.

Chapter III shows the significance of investigating what is conveyed in science teaching about the nature of science. This is achieved by examining the implications of two distinct ways of construing explanation. On the one hand, explanations in science can be seen as <u>exclusive</u> explanations or accounts of phenomena. On the other hand, scientific explanations can be seen as <u>adequate</u> explanations. Arguments show that two different presentations (science as <u>the</u> way to explain, or as <u>a</u> way to explain) have potential for leading to quite distinct views about the power and limitations of science. The potential impact of these views upon pupils is shown to be fundamentally important. In this way, the rationale for attending to views of science within teaching is established.

In Chapter IV, these views about explanation and their potential consequences for pupils are organized within a conceptual framework based upon a comparison of Realism and Instrumentalism. Features of these views of science are logically derived, and become the items which constitute the first category of the analytical scheme: "Category 1: View Of Science Provided For." Portions of science lessons are analyzed also, to illustrate how characterizing them as Realist or Instrumentalist

enables one to make claims about their potential consequences.

Arguments in Chapter V demonstrate the significance of using two further philosophical perspectives for investigating teaching: perspectives derived from epistemology and from the philosophical analysis of teaching. First, the argument considers potential consequences of teaching which fulfills, or fails to fulfill, one or more of the traditional conditions of knowledge: evidence, truth, and belief. Then, distinctions from the philosophical analysis of teaching are shown to reveal separate features of teaching acts which have potential significance for pupils. Distinctions from both these perspectives are synthesized under the concepts "Intellectual Independence" and "Intellectual Dependence." These distinctions thus become the items of the second category of the scheme: "Category 2: Provision For Intellectual Independence Or Dependence."

The Empirical Component

The remainder of the study is concerned with refining the analytical scheme and showing that it can be used reliably. Procedures for these aspects of the empirical component are reported in Chapter VI. Data for the empirical component consist of four science lessons selected from a group of fourteen which were recorded and transcribed verbatim for this study. The rationale for selecting these four lessons is also reported in Chapter VI.

It has been shown that the attempt to characterize a lesson according to the provision it makes for potential consequences to pupils requires information about the context in which that lesson might be

received by pupils. In this study, interviews were used to ascertain context from teachers. An early version of the scheme guided the investigator about the sorts of information required of each interview. This information then becomes an important source of support for making claims about the provisions of classroom discourse.

The first two lesson transcriptions were used as material for checking that the theoretically derived items of the scheme could characterize classroom discourse. Items of this initial version of the scheme which failed to correspond with classroom speech were revised as necessary. Thus a revised version of the scheme was produced. Next, a trial was undertaken to find if the revised scheme could be used reliably.

The trial at determining reliability involved submission of the third lesson and its interview for analysis by three independent judges, the investigator serving as one judge. For the scheme to be reliable, the results of a trial were to yield agreements among judges that were statistically significant at the .01 level of confidence. Failing this, the scheme would be revised, and trials repeated with other lessons until this level was attained. The first trial proved successful, however. The total percentage of agreement among judges was 82.3 per cent, the agreements being estimated as statistically significant at the .01 level of confidence. (Arguments in Chapter VI demonstrate how this significance is estimated.)

Materials relevant to the empirical component of the study are found in the Appendix: the initial and revised versions of the analytical scheme, the instructions sent to independent judges, and two

complete science lessons with their respective interviews. The first of these lessons is the one analyzed by the independent judges. The judges' analyses are presented to show similarities and differences among them; they are not helpful in demonstrating clearly how the scheme is used. Thus a second lesson is appended, which the investigator has analyzed to show reasons for using particular items of the scheme to characterize the discourse.

Instances in which judges disagree in their analyses pose problems germane to the use of the scheme. So, in Chapter VII, such disagreements are examined to reveal practical limitations of the scheme. The remaining discussion in Chapter VII concerns implications of the study for research on science teaching and, ultimately, for supervision of teaching.

CHAPTER II

AN ANALYSIS OF RESEARCH ON SCIENCE TEACHING

As indicated earlier, current paradigms for research on science teaching are unsuitable for dealing with issues of central concern to this investigator.[1] Available classroom observation schemes, representing the "observation paradigm," are not designed to detect intellectual provisions within classroom discourse such as those described in Chapter I. For this reason, a new scheme is developed in this study.

Moreover, the technique of relying upon measures of pupil achievement is not helpful to this study. This technique, called here the "achievement paradigm," can be used to make only weak inferences about the potential of science teaching, for two reasons.[2] First, measures of achievement do not necessarily evidence unique mental events, so they might not permit one to discriminate accurately between importantly different types of teaching. Second, there has to be evidence that measured achievement is indeed a consequence of teaching, and this evidence can come only from simultaneous classroom observation. But, as

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[1]This use of the term "paradigm" has its precedents, for instance N. L. Gage, "Paradigms for Research on Teaching," in Handbook for Research on Teaching, ed. by N. L. Gage (Chicago: Rand McNally and Company, 1963), pp. 94-141.

[2]The phrase "weak inference" is intended in its literal sense, and not in a technical sense such as that used by John Ryder Platt in his paper, "Strong Inference," Science, CXLVI (October, 1964), pp. 347-53.

just mentioned, there <u>are</u> no such devices which analyze teaching for consequences investigated in this study.

Arguments in this chapter support these judgments about the two research paradigms. A "Means-End Model of Education," in Figure 1, is described and then used to represent the unique focus of the two paradigmatic research approaches. Following the introduction of this model, the "observation paradigm" is reviewed and analyzed. A separate section reviews four studies that fruitfully differ from others of this paradigm. Finally, the "achievement paradigm" is analyzed and illustrations are given from representative studies.

<u>A Means-End Model of Education</u>

The model presented in Figure 1 provides a useful way of representing certain features of education which distinguish the two research paradigms.[1]

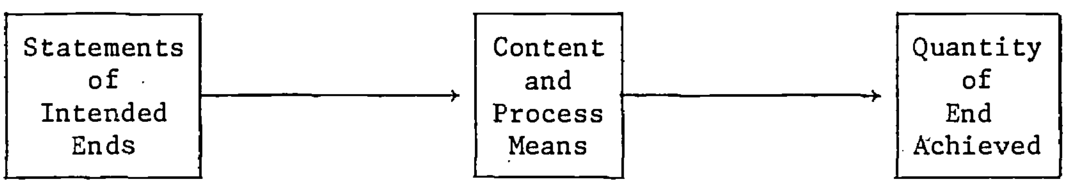

Fig. 1.--A Means-End Model of Education

If one construes education as intentional, then one sees a teacher's speech and actions in a classroom as <u>means</u> calculated to bring about pupils' achievement of predetermined (educational) ends.

[1]For this reason, the model does not represent all aspects of the educational process. For instance, criteria used to select appropriate educational ends are excluded.

The reasoning used to determine optimal means for achieving stated ends is strategic reasoning, implying the notion of deliberation upon and selection of appropriate strategies.[1]

There are probably several types of means which affect the success of teaching. Certainly, the <u>substance</u> of what a teacher says is potentially influential. Other factors, such as types of questions or other aspects of "teaching style," can be expected to influence the success of teaching too. The means used by teachers can be divided into two groups at least: content means, and process means. Content means are defined here as those components of teaching that can be shown logically to <u>make provision</u> for designated educational outcomes.

For instance, if the intended end of a portion of teaching is that pupils obtain specified information about, say, the atomic theory, then that information must be present in the discourse (in some form or other). If it <u>is</u> present, pupils <u>can</u> obtain it, no matter what style of teaching is used. So, according to the model, if substantive, discipline-specific ends are desired, then content logically shown to provide for these ends must be present as means. Content means are logically necessary for teaching to have <u>potential</u> for success. But, process means have no such logical claim for necessary inclusion when planned, discipline-specific ends are desired.

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[1]The phrase "strategic reasoning" is John Eisenberg's. A full account of this conceptualization and its pertinence to historical inquiry appears in his paper "Strategic Reasoning," The Ontario Institute for Studies in Education, 1970. (Mimeographed.)

This distinction (between the logical necessity of content and process means) is central to analyzing the research paradigms. In the following section, the model is used to show the sorts of means investigated by various classroom observation devices. The model is also useful for analyzing the "achievement paradigm." Studies of this type focus on the "quantity of end achieved" and make claims about the effectiveness of teaching in terms of statistical probabilities.

Features of the "Observation Paradigm"

By far the more numerous among devices for analyzing teaching are those which in one way or another yield information about process means, generally enabling one to pattern sociological features of classroom interaction.[1] A second, smaller group of instruments allow coding of discourse according to its logical features, or to the type of subject matter being taught. These two groups are represented and discussed below.

Focus on Process Means: Flanders and Descendants

An observation system developed by Flanders is probably the forebear of all these devices. Use of the Flanders System results in ascribing an "I/D" ratio to a teacher's lesson, amounting to a frequency

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[1] In a recent addition to an existing compendium, Anita Simon and E. Gil Boyer describe in detail the background and methodology of eighty observation instruments. The compendium, now totalling fifteen volumes, is Mirrors of Behavior: An Anthology of Classroom Observation Instruments (Philadelphia: Research for Better Schools, Inc., 1971).

ratio of indirect to direct behaviors influencing pupils.[1]

Basically, the scheme contains three categories: indirect influence, direct influence, and student talk. "Indirect influence" is further divided into the subcategories: accepting feeling, praising or encouraging, accepting and using ideas of students, and asking questions. Subcategories of "Direct influence" are: lecturing, giving directions, and criticizing or justifying authority. During observation, a mark is placed in the matrix to identify the discourse every three seconds. Frequencies in the cells yield the I/D ratio.

There have been many variations upon the Flanders theme. Amidon, Amidon, and Rosenshine have further subdivided categories of the original system to yield the "Expanded Interaction Analysis System."[2] Another system, developed by Parakh, contains seventeen categories.[3] Recently reviewing such devices, Rosenshine reports the availability of an excess of 120 interaction analysis schemes.[4]

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[1]Ned A. Flanders, "Teacher Influence, Pupil Attitudes, and Achievement," in Contemporary Research in Teacher Effectiveness, ed. by Bruce Biddle and William J. Ellena (New York: Holt, Rinehart and Winston, 1964), pp. 196-231.

[2]Edmund J. Amidon, Peggy Amidon, and Barak Rosenshine, Skill Development in Teaching Work Manual (Minneapolis, Minn.: Association for Productive Teaching, 1969).

[3]Jal S. Parakh, "A Study of Teacher-Pupil Interaction in BSCS Yellow Version Biology Classes: Part II. Description and Analysis," Journal of Research in Science Teaching, V (1967-68), pp. 183-192.

[4]Barak Rosenshine, "Evaluation of Classroom Interaction," Review of Educational Research, XL (April, 1970), pp. 279-300.

> Category systems have become very popular in descriptive educational research and in teacher training because they offer greater low-inference specificity and because an "objective" count of a teacher's encouraging statements to students appears easier for a teacher to accept than a "subjective" rating of his warmth.[1]

The emphasis on the frequency and directiveness of teachers' speech illustrates that these instruments are not designed for examining content means within teaching. Instead, they focus on process means.

Focus on Content Means

The second and smaller group of classroom observation instruments concentrates on the logic of discourse and, in some cases, on content and level of conceptualization. Apart from distinctive studies to be discussed in the next section, the few cases that deal with content means are not designed to investigate content that provides for consequences or ends such as those associated with Intellectual Independence or Dependence, or Realist or Instrumentalist view of science.

A focus on the logic of classroom discourse is afforded by an observational instrument developed by Smith and Meux.[2] With this system, logical episodes within teaching can be identified according to twelve forms: defining, describing, designating, stating, reporting, substituting, evaluating, classifying, comparing, contrasting, conditional inferring and explaining. Using this scheme, Smith and Meux found that teachers employ different strategies or orderings of logical episodes in their teaching.

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[1] *Ibid.*, p. 282.

[2] B. Othanel Smith and Milton Meux, "A Study of the Logic of Teaching," U.S.O.E. Cooperative Research Project No. 258. (Urbana: College of Education, University of Illinois, 1962).

Somewhat similar categories appear with others in the "Topic Classification System" developed by Gallagher.[1] This complex system is designed for coding teaching along three dimensions of categories. The dimensions used are: level of style (activity, description, explanation, evaluation-justification, evaluation-matching, expansion), level of instructional intent (content, skills), and level of conceptualization (generalization, concept, data). Content here is defined as referring to " . . . the goal of having the student learn a given body of knowledge. Information, ideas or concepts are presented directly to the student and he is expected to absorb them."[2]

Gallagher summarizes studies using this system:

> The Topic Classification System, devised as a tool for the studying of classroom interaction, proved to be useful in distinguishing variations between teachers, between content areas, and between students. In this respect, the three-dimensional nature of the system provided a basis for looking at attitude and classroom climate dimensions and acted as a basis for analyzing the cognitive content. While the affective dimension of classroom interaction is a reflection of the basic relationship between teacher and student, it is the cognitive dimension that provides the foreground of the instructional environment.[3]

While Gallagher substantially concurs with the priority of content means over process means, it is noteworthy that his system is limited in the types of content it can categorize. After analyzing English, social

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[1] James J. Gallagher, "A 'Topic Classification System' for Classroom Observation," in AERA Monograph Series on Curriculum Evaluation: 6. Classroom Observation, series ed. by Robert E. Stake (Chicago: Rand McNally and Company, 1970), pp. 30-73.

[2] Ibid., p. 40.

[3] James J. Gallagher, "Three Studies of the Classroom," in AERA Monograph Series on Curriculum Evaluation: 6. Classroom Observation, op. cit., p. 102.

science, and biology lessons, he restricts comparisons to the levels and sorts of information detected in the teaching, thus:

> While all classrooms seemed to lean heavily on the use of DESCRIPTION and EXPLANATION topics, <u>science</u> classes seem to do so even more strongly than others. There seems to be a natural tendency for science classes to stick rather closely to the analysis and explanation of events and to avoid topics smacking of evaluation or choice of ideas or concepts.[1]

So, as with other systems, the "Topic Classification System" is not designed to characterize provisions in teaching which are the concern of this study. Even the system designed by Parakh specifically for analyzing science teaching only just touches upon content means relating to the nature of science, with the single category, "Gives or asks for information about the nature of science."[2]

Some Comments on Typical "Observation Paradigm" Studies

In sum, studies representing the "observation paradigm" of research on science teaching typically leave an important feature of classroom discourse unexamined: intellectual provisions relating to the epistemology and view of science in teaching.

Two further aspects of this paradigm warrant mention for the incongruities they present. First, the emphasis upon teaching and learning notwithstanding, Nuthall reports that classroom observation instruments appear generally divorced from identifiable bases in psychological theories of learning. He writes:

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[1] *Ibid.*, p. 104.

[2] Parakh, *op. cit.*

> It must be obvious to the critical reader that what is missing from many of the reported studies is the sense of direction, and controlled orderliness, which can only be provided by adequate theory. The question which prompts itself is: Why, if these studies are supposed to relate to pupil learning in the classroom, are so few of them influenced by the often-taught theories of learning?[1]

Admittedly, this incongruity is not wholly applicable to all observation instruments. But the second is, with specific exceptions reviewed below. Recently, there have been many fruitful inquiries by philosophers into the concepts teaching, training, indoctrinating, learning, and others.[2] Yet classroom observation studies have apparently disregarded these attempts at clarifying the nature of acts that are the target of this paradigm's inquiries.

Distinctive Studies in the "Observation Paradigm"

Studies reviewed in this section are distinctive representatives of the "observation paradigm," for they derive analytical schemes from philosophical perspectives to a greater or lesser extent. The study of Oguntonade draws partly upon philosophy of science.[3] The others are wider in their theoretical grounding, relying additionally upon epistemology and/or the philosophical analysis of teaching. These studies are the only ones known to the investigator which analyze science instruction

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[1]Graham A. Nuthall, "A Review of Some Selected Recent Studies of Classroom Interaction and Teaching Behavior," in *AERA Monograph Series on Curriculum Evaluation: 6. Classroom Observation*, *op. cit.*, p. 27.

[2]For example, C. J. B. Macmillan and Thomas W. Nelson, editors, *Concepts of Teaching: Philosophical Essays* (Chicago: Rand McNally, 1968).

[3]Christopher B. Oguntonade, "An Analysis of Teachers' Verbal Explanations in High School Physics" (unpublished Ed.D. dissertation, Teachers College, Columbia University, 1971).

by using philosophical perspectives.

Oguntonade studied verbal behaviors used by physics teachers when explaining preselected problems in micro-teaching situations.[1] An interaction scheme is developed from Suchman's "Model for the Analysis of Inquiry."[2] The scheme has two dimensions: a pedagogical dimension consisting of the categories Teacher Lectures, Teacher Solicits, and Teacher Responds; and a syntactical dimension consisting of the categories Encounter, System, and Meaning. The syntactical dimension is argued as representing how the discourse corresponds to the nature of physics as inquiry.

The scheme is used by independent judges to code seventy incidents of explanation in micro-teaching. Median percentage agreements for the syntactical dimension are low: 59.5, 58.5, and 55.5 for the respective categories. Oguntonade reports a considerable number of statistical relationships among the dimensions of his scheme, and between these dimensions and the subject matter of the explanation incidents. Of interest is his attempt to further characterize explanation incidents according to the types of explanation used. These types, derived from Nagel's accounts of explanations in science,[3] are universal law, construct, analogy, historical account, and miscellaneous. Although the frequency of these types is reported, no effort is made to

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[1] Ibid.

[2] J. R. Suchman, "A Model for the Analysis of Inquiry," in Analysis of Concept Learning, ed. by H. J. Klausmeir and C. W. Harris (New York: Academic Press, 1966), pp. 177-187.

[3] Nagel, The Structure of Science, op. cit.

relate this feature of explanation incidents to other features detected by his scheme.

An early study by Roberts can be seen as influencing the philosophical approach adopted in the remaining three studies reviewed here.[1] Roberts designed, taught, and evaluated a year's physical science course intended to provide under-achieving pupils with epistemologically sound experiences with physics and chemistry. The instruction was successful with certain pupils, as evident in transcripts of lessons and in records of pupil responses to test questions. The study suggests that it would be promising to concentrate on the epistemology and view of science provided in classroom discourse, and also underscores the potential productivity of basing instruction upon sound philosophical footing.

Prusso constructed a device for diagnosing the epistemological characteristics of science teaching according to four epistemological models: institutional, rational, empirical, and pragmatical.[2] This scheme, called the "PREPISTAN Scheme" PRofile and EPISTemological ANalysis), permits coding of lessons for the accuracy with which the nature and epistemology of several levels of statements in science are conveyed

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[1]Douglas A. Roberts, "An Inquiry into Physical Science Instruction Requiring Inventive Thought by Upper Secondary-School Pupils of Modest Ability and/or Motivation" (unpublished Ed.D. dissertation, Harvard University, 1965).

[2]Kenneth W. Prusso, "The Development of a Scheme for Analyzing and Describing the Epistemological Criteria Adhered to in Secondary School Natural Science Classroom Communication" (unpublished Ed.D. dissertation, Temple University, 1972). The institutional model is derived from Allen Wheelis, The Quest for Identity (New York: W. W. Norton and Company, Inc., 1958), pp. 72-75. The other models are derived from Israel Scheffler, Conditions of Knowledge: An Introduction to Epistemology and Education (Glenview, Illinois: Scott, Foresman and Company, 1965), pp. 2-5.

to pupils. The PREPISTAN Scheme was developed from sectors of philosophy of science, epistemology, and philosophical studies on teaching. Through its use, Prusso clearly demonstrates the power of philosophical distinctions for revealing fundamentally important messages conveyed to pupils during teaching. These messages give information about the meaning of statements in science, and about the nature of science.

A former study by this investigator develops a scheme from similar areas of philosophy, and enables one to classify instances of teaching according to three philosophical models.[1] Despite several shortcomings, this study shows the feasibility of a philosophical analysis of classroom teaching. Moreover, by virtue of appended lesson transcripts, the study affords evidence of some disregard for epistemological rigor and honest portrayal of science in science teaching.

Kilbourn's study deserves mention for the manner in which epistemology and philosophy of science are used to create a scheme for analyzing arguments in science texts.[2] The study analyzes a portion of the

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[1] A. H. Munby, "The Use of Three Philosophical Models of Teaching to Analyze Selected Science Lessons" (unpublished M.A. thesis, University of Toronto, 1969). The models employed are from Israel Scheffler, "Philosophical Models of Teaching," Harvard Educational Review, XXXV (Spring, 1965), pp. 131-43. Chronologically, Prusso's work was commenced prior to studies of the present investigator.

[2] Brent Kilbourn, "Analyzing the Basis for Knowledge Claims in Science Textbooks: A Method and a Case Study," The Explanatory Modes Project: Background Paper No. 6. Toronto: The Ontario Institute for Studies in Education, 1971. (Mimeographed.)

BSCS "Blue Version" text in which claims are made about Australopithecus.[1] Kilbourn's analysis reveals an almost gross neglect of proper warrant for these knowledge claims. This suggests that instructional materials, as well as teaching, might be profitably investigated for the manner in which knowledge claims are supported.

Studies mentioned in this section are quite distinctive in their approach to analysis by being philosophically grounded, to a greater or lesser extent. So, they differ radically from plentiful and typical classroom observation studies reviewed previously. The distinctiveness of the present study is the attempt to characterize science teaching according to significant intellectual consequences provided by the discourse.

Features of the "Achievement Paradigm"

Studies reviewed thus far represent one method by which the potential of teaching might be investigated. The potential of teaching has also been assessed by inference from measures of pupil achievement. This approach has been called the "achievement paradigm," for purposes of this study. Arguments in this section show that the "achievement paradigm," and studies representing it, are not suited to investigating consequences with which this study is concerned, for two reasons. First, measures of achievement do not necessarily evidence unique mental states, thus they might not permit one to discriminate between them. Second,

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[1]Biological Sciences Curriculum Study, Biological Science: Molecules to Man (Boston: Houghton Mifflin Company, 1968), pp. 659-65.

inferences about teaching made on the basis of achievement measures are necessarily weak if no account is taken of what, in fact, classroom discourse itself provides. Arguments which make these points are analytical in character, and are illustrated with representative studies of the "achievement paradigm."

Two Difficulties with the "Achievement Paradigm"

Studies of interest to this discussion attempt to measure so-called "teaching effectiveness." Generally, speaking in terms of the Means-End Model, one compares the different quantities of end achieved by various types of teaching. And, when varieties of teaching are identified by the presence of different process means, inferences can be made as to which processes appear more productive of ends, thus more effective. The use of statistical procedures to determine the significance of these findings clearly indicates that the reasoning used is probabilistic, and is quite distinct from strategic reasoning. The investigator contends that inferences about teaching effectiveness, when based on probabilistic reasoning, are limited by conceptual problems.

First, a point made by Jane Roland, in quite another context, reveals the possibility that achievement measures are unable to distinguish between substantially different types of teaching. Her point suggests that quite distinct mental states might give rise to the same response.[1] So the response "Columbus discovered America" to the

[1] Jane Roland, "On the Reduction of 'Knowing That' to 'Knowing How'," in Language and Concepts in Education, ed. by B. Othanel Smith and Robert H. Ennis (Chicago: Rand McNally, 1961), pp. 59-71.

question "Who discovered America?" can reasonably imply either that the respondent _knows how_ to answer the question (as a result of drilling or the like), or that he _knows that_ the proposition "Columbus discovered America" is true (as a conclusion to arguments in teaching that are built upon a systematic examination of available evidence, perhaps). Since similar responses _can_ represent quite distinct mental states, uncertainty arises about the kinds of mental states evidenced by achievement on tests. The effect of this uncertainty is to weaken inferences about teaching effectiveness. That is, if drilling pupils in the correct response, or providing all the arguments for the response, can both lead to identical responses on an achievement test, the test cannot discriminate between significantly different types of teaching. But, when using the "achievement paradigm's" approach, one needs to be quite sure that unique mental states are evidenced by the data, quite unambiguously.

Second, Scheffler, among others, attempted to repudiate the thesis that teaching implies learning.[1] The lack of conceptual linkage between the concepts "teaching" and "learning" would automatically limit the strength of inferences about the one affecting the other. This last point can be demonstrated by returning to the Means-End Model of Education, in Figure 1. The model shows what factors must be considered if inferences about teaching effectiveness are to be strong.

[1] Israel Scheffler, _The Language of Education_ (Springfield, Ill.: Charles C. Thomas, Publisher, 1960), especially chapters ii and iv.

Clearly, whatever the amount and type of end produced, if any support is advanced for the claim that achievement is a function of teaching, then it must be shown that the teaching itself logically <u>can or cannot</u> produce the measured outcome. That is, content means appropriate to the measured ends must be <u>shown</u> to be present in the discourse. As the following examples reveal, this condition is generally not fulfilled. And, in cases where it is, content means are quite different from those examined in this study. Indeed, a recent and authoritative review of 150 studies on learning in science reports not a single study that deals with the intellectual consequences investigated here.[1]

Sample Studies in the "Achievement Paradigm"

Citron and Barnes examined results of varied teaching patterns on achievement in problem solving and concept formation in biology teaching.[2] Here the Flanders System was used to identify variation in process means. This system, it will be recalled, neglects content means. Since there is nothing to indicate what different provision the different types of teaching made for "problem solving" and "concept formation" (the achievement variables examined), resulting inferences about the "effects" of varied teaching patterns are necessarily weak.

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[1] Maurice Belanger, "Learning Studies in Science Education," *Review of Educational Research*, XXXIX (October, 1969), pp. 377-95.

[2] Irvin M. Citron and Cyrus W. Barnes, "The Search for More Effective Methods of Teaching High-School Biology to Slow Learners through Interaction Analysis. Part I: The Effects of Varying Teaching Patterns. Part II: The Effects of Various Constant Teaching Patterns," *Journal of Research in Science Teaching*, VII (Spring, 1970), pp. 9-28.

Many similar studies have been reviewed by Rosenshine and Furst.[1] In labelling these as "process-product" studies, the authors seem to suggest that no attention is given to content means within the instances of teaching studied. Rosenshine and Furst categorize the objects of their review in a most useful way: according to teaching variables examined. Eleven are reported: clarity of presentation, variability of materials and teaching devices, enthusiasm of the teacher, task-oriented and/or businesslike behaviors of teachers, use of student ideas and general indirectedness, criticism, use of structuring comments, types of questions asked, types of elicitation of responses (probing), level of instructional difficulty, and student opportunity to learn criterion material--"criterion" referring to the content of tests that measure achievement.

This last variable is clearly concerned with content means, and an example of a study investigating this variable is appropriate. It will be seen, though, that the promise of this approach diminishes in light of Roland's point, above, and in light of the research design used. According to Rosenshine and Furst, studies employing the last variable ("student opportunity to learn criterion material") attempt to relate material covered in class and the class criterion score on the instrument used to measure the effectiveness of instruction. Thus, Shutes coded lesson transcripts for eleven variables: relevance of

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[1]Barak Rosenshine and Norma Furst, "Research on Teacher Performance Criteria," in Research in Teacher Education: A Symposium, ed. by B. Othanel Smith (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1971), pp. 37-72.

lesson context to test items, clarity of divisions in the lessons, examples, digressions, topics covered, applications, rules relating to examples, functions served by introductions, and functions served by conclusions.[1]

Importantly, in Shutes' and similar studies the selection of content variables is governed by the test to be submitted to students. This, Rosenshine and Furst acknowledge, could lead to significant correlations being interpreted as measures of the degree to which teachers trained pupils on criterion items (intentionally or unintentionally).[2] So the research design yields doubt about the type of mental state evidenced by measures of learning (Roland's point, mentioned earlier).

Reporting on the "opportunity to learn" variable, Rosenshine and Furst conclude:

> Such a variable has not been sufficiently considered in the analysis of process-product studies; in almost all studies no measure was taken of student opportunity to learn, and consequently all classes were treated as if they had equal opportunity to learn.[3]

This point applies precisely to the final study reviewed here to exemplify the "achievement paradigm." A recent study by George[4] illustrates the dangers of using this research paradigm to investigate the

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[1] R. E. Shutes, "Verbal Behaviors and Instructional Effectiveness" (unpublished Ph.D. dissertation, Stanford University, 1969).

[2] Rosenshine and Furst, op. cit., p. 49.

[3] Ibid., p. 62.

[4] Kenneth D. George, "The Effects of BSCS and Conventional Biology on Critical Thinking," Journal of Research in Science Teaching, III (1965), pp. 293-99.

potential of teaching.

Using a comparative design, George investigated gains in critical thinking among classes studying the three versions of the Biological Sciences Curriculum Study and a "conventional" biology course. The study involved a pretest and post-test design using the Watson-Glaser Test of Critical Thinking Ability, the tests being administered near the beginning and end of the school year. From the statistical analysis, in which intelligence and pretest scores were held constant, it was found that classes using the Blue Version of BSCS attained statistically significant increases in critical thinking ability over classes using other versions of BSCS or the "conventional" biology course. While efforts were made in the statistical treatment to minimize the influence of unknown variables, a number of factors remained that might have interfered with the experiment to an unknown extent. As George states:

> The results of this study were influenced not only by the biology program being used but by the methods the teacher used in presenting the program to the pupils. The BSCS program and philosophy have become so widely known that it is nearly impossible to identify a high school biology teacher that has not been influenced with this philosophy. For this reason, the conventional teachers might have incorporated some of the BSCS materials into their program.
>
> The opposite point of view can also be taken. It has become popular to be known as a BSCS teacher. For this reason many teachers have adopted the BSCS program but have not adopted the methods that must be used with this program.
>
> Because it was impossible to hold the teacher's philosophy and methods constant, these factors influenced pupil achievement to an unknown extent.[1]

Clearly, the inferences made about the teaching investigated by George are necessarily weak. And, the only way in which they might be

[1] *Ibid.*, p. 298.

strengthened is by direct observation of the teaching itself. Without this sort of evidence, one cannot make strong inferences about the facets of total classroom experience which might contribute to the ends that are measured.

So measures of teaching effectiveness that disregard the provision of content means are of limited power, and the present investigator finds the "achievement paradigm" not suited to the purpose of this study.

Summary

This chapter has reviewed paradigmatic research on science teaching. The Means-End Model of Education, in Figure 1, provides a context in which to understand the "observation paradigm" and "achievement paradigm" of research on teaching. It has been argued that neither paradigm offers ways to investigate potential consequences of the epistemology of classroom discourse and the view of science presented in it. Strong inferences about this potential cannot be made using achievement measures alone. Such measures would have to be supplemented with data obtained from classroom observation. So the "achievement paradigm" is inappropriate for this study. No scheme is available for characterizing teaching according to this type of potential, even though the "observation paradigm" _is_ appropriate. Thus, the study develops such a device, and shows that the potential consequences the scheme can detect are indeed of fundamental importance.

CHAPTER III

SCIENCE AND EXPLANATION

In Chapter II, current paradigms for research in science teaching were shown to be inadequate for investigating potential consequences of classroom discourse which are the concern of this study. There are no available means for detecting the provisions that can result from presenting different views of science and different ways of supporting knowledge claims in teaching. This chapter and the two that follow provide the rationale for investigating such provisions, and eventuate in the analytical scheme.

The argument in this chapter demonstrates the importance of investigating the view of science presented in teaching. In Chapter IV, the first category of the analytical scheme is developed, portions of it drawing from the analysis undertaken below. The rationale for investigating provision for Intellectual Independence and Dependence, and the development of the second category of the scheme, are topics for Chapter V.

The argument in this chapter is grounded in philosophy of science. Issues concerning scientific explanation have to be dealt with in order to point up the rationale for investigating the view of science present in classroom discourse. After examining different accounts of explanation, the investigator can relate these to fundamentally important consequences to pupils.

The argument begins by showing that science has, among other features, an explanatory function. This feature of science is important to the present study, for science can then be seen as providing pupils with a means for explaining phenomena. And, since explanation enables one to make unfamiliar events intelligible, science teaching has the potential for enabling pupils to cope with their experiences.

But explanations in science can be construed in two distinctive ways, called here the Deductive Paradigm and the System Paradigm, after terminology used by Meehan.[1] Both these accounts are described below, not to set the two paradigms in competition, but to reveal how each carries with it quite different implications regarding aspects of the nature of science. So, it is argued, presenting scientific explanation in ways identifiable with one or the other paradigm provides for fundamentally and significantly different consequences for pupils regarding views about science, and about explanation.

This analysis, then, differs importantly from a purely technical analysis of the Deductive Paradigm and the System Paradigm in which one might debate the formal and functional character of explanation. Here, the concern is to focus upon features of the paradigms that suggest significantly different consequences regarding science and explanation, so far as pupils are concerned. And, as noted in Chapter I, conceptual distinctions resulting from an analysis which takes account of the provisions of teaching can do an injustice to the philosophical positions

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[1]Eugene Meehan, Explanation in Social Science: A System Paradigm (Homewood, Illinois: The Dorsey Press, 1968).

giving rise to them in the first place. Nevertheless, it will be shown that making these distinctions allows for discrimination between portions of teaching that provide for quite different intellectual consequences.

The Explanatory Function of Science

In the introduction to The Structure of Science, Ernest Nagel distinguishes between prescientific knowledge (common sense) and science, by suggesting that the former provides reliable information about the environment through observation and classification, while the latter stems from the wish to accompany such information with explanations of phenomena observed:

> It is the desire for explanations which are at once systematic and controlled by factual evidence that generates science; and it is the organization and classification of knowledge on the basis of explanatory principles that is the distinctive goal of the sciences.[1]

Nagel's assertion that science is, in part, an explanatory device is supported by other writers in the philosophy of science. Toulmin, for example, illustrates the explanatory nature of science by demonstrating that Snell's law for optical refraction presents a way of explaining such phenomena as the apparent bending of a stick when partially immersed in water.[2] Hempel also argues that science is concerned with explanation:

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[1] Ernest Nagel, The Structure of Science: Problems in the Logic of Scientific Explanation (New York: Harcourt, Brace and World, Inc., 1961), p. 4.

[2] Stephen Toulmin, The Philosophy of Science: An Introduction (New York: Harper and Row, 1960), pp. 62-3.

> One of these (pervasive human concerns) is man's persistent desire to improve his strategic position in the world by means of dependable methods for predicting and, whenever possible, controlling the events that occur in it. The extent to which science has been able to satisfy this urge is reflected impressively in the vast and steadily widening range of its technological applications. But beside this practical concern, there is a second basic motivation for the scientific quest, namely, man's insatiable intellectual curiosity, his deep concern to know the world he lives in, and to explain, and thus to understand, the unending flow of phenomena it presents to him.[1]

From these accounts, it seems reasonable to describe science as serving an explanatory function. Although this description fails to reveal properties that make the discipline distinctive, it suggests that the fashion in which one views science might be controlled by one's view of scientific explanation, and vice-versa. For this reason, the effort to identify potential consequences of science teaching begins with an analysis of ways of viewing explanation.

Despite the potential of using conceptual distinctions about explanation for characterizing science teaching, the resulting framework ignores the descriptivist position which states that science is not to be considered as a device for explaining phenomena, but is best construed as a manner of describing phenomena. Accordingly, the terminology of science, including such terms as "ions," "energy," etc., is regarded as an economical description of the world. In fact, since the concern of this chapter is for developing conceptual distinctions rather than for debating positions, descriptivism holds no threat to the current argument. However, discussion in Chapter IV on the status of

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[1] Carl G. Hempel, "Explanation in Science and in History," in The Philosophy of Science, ed. by P. H. Nidditch (Oxford: Oxford University Press, 1968), p. 54.

theories introduces descriptivism as an alternative, and it is discussed at length at that point.

The following discussion of the Deductive Paradigm and the System Paradigm draws primarily from the works of Hempel and Oppenheim,[1] and of Meehan,[2] respectively. It will be seen that proponents of the Deductive Paradigm characterize explanation as conforming to a logical deduction from a covering or general law.[3] Dray has argued that this account fails to accommodate historical explanation,[4] and others, such as Hanson[5] and Meehan,[6] point out that the Deductive Paradigm inadequately represents the derivation of explanations, as in scientific discovery. So the System Paradigm offers an alternative account of explanation,

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[1]Carl G. Hempel and Paul Oppenheim, "The Logic of Explanation," in Readings in the Philosophy of Science, ed. by H. Feigl and M. Brodbeck (New York: Appleton-Century-Crofts, 1953) pp. 319-52.

[2]Meehan, Explanation in Social Science, op. cit.

[3]The presentation here of a single definition of explanation is thwarted by the need for the analysis to remain uncommitted toward any particular position. Siding with one or the other of the two accounts of explanation would necessarily eventuate in an analytical scheme which judged science teaching rather than described the potential impact of the teaching. Accordingly, definitions of explanation are given separately for the Deductive and System Paradigms.

[4]William Dray, Laws and Explanation in History (Oxford: Oxford University Press, 1957).

[5]Norwood Russell Hanson, Patterns of Discovery (London: Cambridge University Press, 1965).

[6]Meehan, Explanation in Social Science, op. cit.

with a focus upon its function and derivation.[1] This focus on the functional aspects of explanation is shown to open the way to considering how scientific explanations can be seen as competing with other types of explanations that individuals might prefer to use in explaining their environments, such as religious or magical explanations. It is argued in what follows that the Deductive Paradigm logically precludes considerations of this sort by pupils, and so the two paradigms appear to be useful for conceptualizing different views about the ranges and limitations of scientific explanation and of science. A separate section is given to discussion of how what is implied or stated about explanation in teaching can influence pupils' views of such matters.

Features of the Deductive Paradigm

The first section on the Deductive Paradigm begins with four accounts of explanation which appear representative of this paradigm, accounts by Hempel and Oppenheim, Swift, Hospers, and Feigl. (The latter three are discussed here in an elaboration of a basic pattern of explanation proposed by Hempel and Oppenheim.) These accounts point up the attributes of explanation and the conditions that explanations must satisfy within the Deductive Paradigm. Such attributes and conditions,

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[1]A debate between the Deductive Paradigm and the System Paradigm would require that the current analysis take account of Richard S. Rudner's efforts to reduce functionalism (as in the System Paradigm) to descriptivism, as found in his Philosophy of Social Science (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1966). But since the Deductive Paradigm and System Paradigm are used here for making conceptual distinctions between possible consequences of different types of science teaching, an analysis of Rudner's arguments is not helpful. Furthermore, Rudner's reduction appears to be based upon a Realist view, and ignores the functional elements of explanation that some consider irreducible.

which are significant for the bearing they have upon views of science, are then discussed in the second section on the Deductive Paradigm, under the headings: Pseudo-explanations, Historical Explanations, the Condition of Truth, and Predictability.

A Basic Pattern of Scientific Explanation: Hempel and Oppenheim

In an early account of explanation, Hempel and Oppenheim assert that the basic pattern of scientific explanation consists of explanandum and explanans. The explanandum (E) is a statement of the phenomenon to be explained. The explanans states the antecedent conditions attending the phenomenon ($C_1, C_2, \ldots, C_k$) and the general laws which hold ($L_1, L_2, \ldots, L_r$). Accordingly, the Deductive Paradigm is represented by the following:

$$\left.\begin{array}{ll}\text{(Certain conditions hold)} & C_1, C_2, \ldots, C_k \\ \text{(Certain general laws hold)} & L_1, L_2, \ldots, L_r\end{array}\right\} \text{(Explanans)}$$

Therefore, E (Explanandum), the phenomenon occurs.

The explanandum E is the result of a logical deduction from the explanans.[1] According to this exposition, there are a number of conditions to be fulfilled if the explanation is to be granted as sound: the explanandum must be a logical consequence of the explanans, that is, it must be deducible from the explanans; the explanans must contain general laws; the explanandum must have empirical content such that it is in principle capable of test; and finally, the "empirical condition for

[1]Hempel and Oppenheim, "The Logic of Explanation," op. cit., p. 322.

adequacy" requires that the statements which constitute the explanans must be true.

Hempel and Oppenheim argue that the formal analysis they present is applicable to scientific prediction as well as to explanation:

> It may be said, therefore, that an explanation is not fully adequate unless its explanans, if taken account of in time, could have served as a basis for predicting the phenomenon under consideration.[1]

The importance of scientific explanation, it is claimed, is partly due to its potential predictive capability.

Later, in the same paper, attention is given to explanation in non-physical science. There it is shown that causal explanations are sometimes found inadequate, either because the events to be explained involve individuals or groups and hence contain no inherent repeatability, or because the events to be explained involve purposive behaviors which call for motivational or teleological explanation rather than for causal explanation.

For Hempel and Oppenheim, the Deductive Paradigm appears synonymous with scientific explanation, and there is an important feature of this view which arises in their discussion of the concept "entelechy" (a postulated "vital force" alleged to give rise to life). In their argument, it seems that efforts at explaining which fail to meet one or more of the conditions of the Deductive Paradigm are not to be considered as explanations at all. They state:

> The crucial point here is not--as it is sometimes made out to be--that entelechies cannot be seen or otherwise directly observed; for

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[1] Ibid., p. 323.

> that is true also of gravitational fields, and yet reference to such fields is essential in the explanation of various physical phenomena. The decisive difference between the two cases is that the physical explanation provides (1) methods of testing, albeit indirectly, assertions about gravitational fields, and (2) general laws concerning the strength of gravitational fields, and the behavior of objects moving in them. Explanations by entelechies satisfy neither of these two conditions.[1]

It is then concluded that the concept "entelechy" is deprived of all explanatory import since it does not comply with the logical condition that the _explanans_ must contain general laws.

It will be seen that features of the Deductive Paradigm, such as those derived by Hempel and Oppenheim, recur in the three further representative accounts of the paradigm that follow. Additional features emerge, as well.

Swift's Triadic Pattern of Scientific Explanation

Swift, drawing on the account by Hempel and Oppenheim, provides an analysis of explanation which shows the pattern of scientific explanation to be triadic. A scientific explanation consists in a generalization, evidential statements, and a conclusion.[2] Of interest here is Swift's interpretation of the condition of truth, which Hempel and Oppenheim argue must be fulfilled. Swift relies upon a notion of supporting evidence which commits him to the stance of inducing generalizations from supporting empirical evidence. Presumably, then, a sound explanation depends somehow upon sufficient evidence, but Swift mentions

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[1] _Ibid._, p. 330.

[2] Leonard F. Swift, "Explanations" in _Language and Concepts in Education_, ed. by B. Othanel Smith and Robert H. Ennis (Chicago: Rand McNally & Company, 1961), pp. 179-94.

no criterion by which the sufficiency of evidence might be judged.

Hospers: Several Kinds of Law

Similar properties are evident in John Hospers' analysis of explanation. The answer to "What is explanation?" is, he states, quite simple:

> . . . to explain an event is simply to bring it under a law; and to explain a law is to bring it under another law. It does not matter whether the law is one about purposes or not, or whether it is familiar or not; what matters is that if the explanation is to be true (and we surely seek true explanations, not false ones), the law invoked must be true: indeed, this is already implied in the use of the word "law," which refers to a true, i.e. really existing, uniformity of nature; if the uniformity turned out to be only imaginary, or having exceptions, we would no longer call it a law.[1]

Hospers' assertion of the need for true laws is qualified later by suggesting that some explanations may contain hypotheses which are not known to be true. He then considers the place of deduction in explanation, concluding:

> . . . whether deducibility is a necessary condition for explanation or not, it is not a sufficient condition. One can deduce that this watch will not work from the premises that watches will not work if gremlins get into them and that gremlins are in fact in this watch. Yet no one would accept this as an explanation for the misbehavior of the watch.[2]

An additional feature to be noted from Hospers' analysis is that explanations of phenomena and events may be considered as subsumed beneath the "covering law" in the Deductive Paradigm provided that laws or hypotheses about human purposes can be constructed. For this reason,

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[1]John Hospers, "What is Explanation?" in Essays in Conceptual Analysis, ed. by Anthony Flew (London: Macmillan and Co., 1956), pp. 98-99.

[2]Ibid., p. 106.

Hospers can be interpreted as proposing that historical events may be explained in a fashion consistent with the Deductive Paradigm.

Feigl: Several Levels of Deduction

Feigl depicts deduction in explanation at several levels, as follows:

Theories, 2nd order:	Still more penetrating interpretation (still higher constructs).
Theories, 1st order:	Sets of assumptions using higher-order constructs (results of abstraction and inference).
Empirical Laws:	Functional relationships between relatively direct observable (or measurable) magnitudes.
Description:	Simple account of individual facts or events (data) as more or less immediately observable.[1]

Feigl asserts that the explanans (which for Hempel and Oppenheim only contains true conditions and laws) actually contains assumptions and higher order constructs; he notes, for instance:

> The constructs of this theoretical level (2nd order) usually concern the micro-structure of the observed macro-phenomena, i.e., they involve existential assumptions (atom, electron, photon-hypotheses) or constructs of the abstract mathematical order (energy, entropy, tensors, probability functions, etc.).[2]

Also of interest in this study is the way in which Feigl (like Hempel and Oppenheim) apparently condemns explanations which are not scientific:

> It is agreed that scientific explanation differs sharply from the

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[1] Herbert Feigl, "Some Remarks on the Meaning of Scientific Explanations" in Readings in Philosophical Analysis, ed. by H. Feigl and W. Sellars (New York: Appleton, 1949), pp. 510-14. The representation above is adapted from that appearing on p. 512. As Feigl notes, it is to be, ". . . read from the bottom up!"

[2] Ibid., p. 512.

> pseudo-explanations of the animistic, theological or metaphysical types in that the explanatory premises of legitimate science must be capable of test, and must not be superfluous (i.e., not redundant in the light of the principle of parsimony). The significance of the premises and verbalisms of pseudo-explanations is usually purely emotive, i.e., pictorial and emotional.[1]

Feigl does not make it clear, as Hempel and Oppenheim did not in discrediting entelechies, why explanations other than scientific ones are to be reduced to the rank of "pseudo-explanations."

Attributes of Explanation in the Deductive Paradigm

These accounts reveal four attributes of the Deductive Paradigm which are relevant to how one views explanation, and consequently to how science itself might be viewed. First, the accounts suggest that explanations which incorporate teleological or purposive statements are not explanations, but "pseudo-explanations." Second, implicit in the Deductive Paradigm is the requirement that all explanations, even historical explanations, must meet the condition of subsumption beneath a general law. Third, the condition of truth attaching to the general law appears to vary from account to account. Fourth, explanations must have predictability and repeatability. These attributes are discussed separately below, to show how each carries important understandings about explanation.

"Pseudo-explanations"

As already mentioned, one feature of the foregoing accounts of the Deductive Paradigm is the implication that explanations which do not

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[1] *Ibid.*, p. 510.

fit the paradigm are not considered as explanations at all. Instead, they are dubbed "pseudo-explanations." Hospers, for instance, asserts that no one would ascribe a watch's misbehavior to gremlins in it.[1] Feigl dismisses the propriety of animistic, theological or metaphysical explanations; for him, the premises of these are ". . . usually purely emotive . . . ."[2] Hempel and Oppenheim argue that "entelechy" is not an explanatory concept.[3]

There are serious problems with these views about "pseudo-explanations," and these problems have an impact on how one might view science.

First, it is inaccurate to state that such explanations are "pseudo-explanations" just because they fail to meet conditions which are found to account for scientific explanations. In Hans Driesch's system, "entelechy" is an explanatory concept: it was used to explain how a divided sea urchin embryo, at an early developmental stage (gastrula), developed into entirely healthy and symmetrical larvae.[4] "Entelechy" fitted the pragmatic criterion.

Second, it is debatable that "usually purely emotive" explanations should be discredited. After all, as Hempel notes, explanations

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[1] Hospers, op. cit.

[2] Feigl, op. cit.

[3] Hempel and Oppenheim, op. cit.

[4] An informative account of Hans Driesch's work at the end of the nineteenth century may be found in Frederick B. Churchill, "From Machine-Theory to Entelechy," Journal of the History of Biology, II (Spring, 1969), pp. 165-85.

stem from a desire or wish to explain.[1] All explanations thus must satisfy some personal (emotional) need. Indeed, proponents of the Deductive Paradigm have been criticized for omitting this important point: that explanations must satisfy a purpose, a "need to explain."[2] (Gremlins in watches may well satisfy a "need to explain" the failure of a watch.)

In sum, it seems more accurate to speak of such "pseudo-explanations" as "<u>pseudo-scientific</u> explanations." Without this piece of context, science is being presented as the only legitimate, sound, and acceptable way of explaining phenomena--as if the term "explanation" were synonymous with the term "science."

Historical Explanations

There are two problems with viewing historical explanations as fitting the Deductive Paradigm (an interpretation strongly suggested by Hospers' analysis, as noted above on pages 50-51). First, to do so, one has to assume that man acts predictably under exactly the same circumstances. Second, as Dray has pointed out, the picture of historical explanation one sees in the Deductive Paradigm misrepresents the nature of historical inquiry.[3]

Dray has denied the appropriateness of the "covering law" condition for historical explanations. He argues that some historical

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[1] Hempel, *op. cit.*

[2] Dray, *op. cit.*

[3] *Ibid.*

explanations of action are ". . . reconstructions of an agent's calculation of means to be adopted toward his chosen end, in the light of the circumstances in which he found himself."[1] Thus, historical explanations reveal that what was done was thought to be the thing to do under the circumstances (in achieving a particular goal), not what _is_ done on all such occasions.[2]

These problems suggest that the Deductive Paradigm is _not_ an appropriate way to view historical explanations. Yet, if pupils are taught about explanation only in a way consistent with the Deductive Paradigm, they could well get the impression that human behaviors are regulated by general laws of a scientific type. Ergo science would be seen as having the potential for explaining all human events.

The Condition of Truth

Quite clearly, the importance of the condition of truth for an explanation is inviolate. (It makes no sense to say simultaneously that a statement explains and is false.) The significance of the condition of truth seems to lie in how truth is established, and for whom it holds. That is, explanations incorporating entelechy were considered as true by Hans Driesch, but they are false for Hempel and Oppenheim. So the way in which an explanation is counted as true has significant implications for the way in which explanation is understood.

For instance, if an explanation fitting the Deductive Paradigm

[1] _Ibid._, p. 122.

[2] _Ibid._, p. 124.

is stated in an "ordinary language" context (such as that of the example in Chapter I), pupils <u>can</u> derive the understanding that scientific explanations are eternally true, instead of "true for science and for now." And so, the logical implication provided by the teaching is that the covering law must be true in an absolute sense.

Thus, the way in which explanations are presented can affect how one views science and, accordingly, how one views explanation as a process. (Whether or not teaching provides pupils with means to judge the truth of knowledge claims is an important feature of the Intellectual Independence and Intellectual Dependence category of the scheme as developed in Chapter V. The issue of truth is discussed more fully at that time.)

<u>Predictability</u>

The condition that explanations must have predictability carries two sorts of implications. The first concerns the <u>appropriateness</u> of the Deductive Paradigm for characterizing explanations in science. The second concerns how one <u>understands</u> scientific explanations and their limitations. Since the present discussion is not a formal debate between the Deductive Paradigm and the System Paradigm, implications of the first sort are ignored.[1] The second sort is more germane, however.

The point to be made about predictability is parallel to previous points appearing above. Although scientific explanations are

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[1]A useful account of statistical explanations and their resulting predictability is given by Nicholas Rescher, "Fundamental Problems in the Theory of Scientific Explanation," in <u>Philosophy of Science: Delaware Seminar</u>, ed. by W. L. Reese (New York: John Wiley and Sons, 1963) II, pp. 41-60.

required to lead to predictions, this does not imply that all explanations must exhibit that same property, in order to count them as being explanations. Indeed, if an explanation is personally satisfying of itself, there is no reason to impose further conditions upon it. Once again, the Deductive Paradigm appears to impose overly stringent regulations upon all explanations. From this, pupils might understand that unless predictions can be made with explanations which might be more satisfying than scientific ones, then those personally preferred explanations do not count as explanations at all.

Summary

In this section, certain attributes of explanation in the Deductive Paradigm have been shown to be overly stringent criteria to apply to explanations in general. If pupils are presented only the Deductive Paradigm, they could be led to believe that the only types of explanation that are acceptable are scientific ones. Furthermore, since science and explanation are related (because science has an explanatory function) it is possible that such thinking might result in notions of a limitless capability of science to explain.

Before potential consequences to pupils can be discussed further, two important claims have to be substantiated. The first claim is that an alternative way of construing explanation is available--the System Paradigm. The second claim is that science is limited because there are other ways to explain (and these are legitimate), and because there are certain "human phenomena" which science is not designed to be able to explain. Arguments for these claims appear in the following sections.

Features of the System Paradigm

The phrase "System Paradigm" is used here to parallel the account of explanation presented by Meehan.[1] This alternative to the Deductive Paradigm is described fully in this section to show how it yields quite different views about explanation and, thus, about science. By examining the implications of presenting different views of scientific explanation to pupils, the investigator is able to show, in a later section, the importance of investigating views of science provided in teaching discourse.

On the Judgment of Explanations

The core of the System Paradigm is provided in Meehan's definition:

> Systems are formal logical structures, sets of variables, and the rules governing their interactions. One of the basic elements in any explanation, therefore, will be a system. However, since explanations must have objects, must be relevant to something in human experience, each explanation will also involve a description which contains the events to be explained. Construed as a process, explanation is the application of a logical system to a description.[2]

Meehan argues that since description is of man's experience, which is of the past, and since "Nothing in the canons of logic permits a deductive inference from observed experience to either the unexperienced past or future . . . ," then timeless or general propositions properly belong to the logical world rather than to the empirical world.[3] Consequently:

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[1] Eugene Meehan, Explanation in Social Science: A System Paradigm, op. cit.

[2] Ibid., p. 31. [3] Ibid., p. 32.

> There is no need, in the system paradigm, to ask for empirical statements that hold into eternity. Instead, we ask under what circumstances we can expect a given set of relations to hold with reference to empirical data.[1]

Meehan's use of the word "description" is synonymous with "concept." He identifies two types of concepts: classifications which organize perceptions, and relational propositions which connect classifications.

Meehan argues that the System Paradigm admits of no criteria for establishing the truth or falsity of an explanation. Instead, as distinct from the Deductive Paradigm's condition of truth, an explanation is to be judged as more or less useful for a specified purpose.[2]

Complexes of Relations

Another difference between the two paradigms concerns the focus used in depicting the process of explanation. The focus of explanations in the System Paradigm is upon the complex of relations surrounding an event. In the Deductive Paradigm, the focus is upon particular features of classes of events, which leads to examinations of samples of that class. Meehan illustrates this focus of the System Paradigm by an example drawn from the physical sciences. In this example, the illumination of a light bulb is explained with a system calculus accounting for the variables: number of batteries, amount of illumination, amount of voltage, amount of current, amount of resistance, and filament

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[1] Ibid., p. 33.

[2] There are other criteria to be satisfied by an explanation, such as generalizability, and a logical link between explanans and explanandum, as Nagel suggests. (Nagel, op. cit., pp. 503-546.) While Meehan does not deal with these extensively, the System Paradigm emphasizes the pragmatic criterion admirably; and this is its major strength.

temperature.[1] These variables within the calculus represent the complex of relations surrounding the event.

This focus of the System Paradigm upon complexes of relations surrounding events closely parallels Dray's account of historical explanation: "a reconstruction of an agent's calculation of means to be adopted toward his chosen end, in the light of the circumstances in which he found himself."[2]

The Goals of Explaining

The origin of the System Paradigm exemplifies further the differences between the two paradigms. According to Meehan, the System Paradigm provides an adequate account of the process of explanation which is not provided by the Deductive Paradigm. The reliance of the latter upon empirical laws would, if the Deductive Paradigm were accepted, severely restrict the social scientist's ability to explain. One would have to generate covering laws to account for human action. Meehan claims that the System Paradigm presents an alternative definition of explanation which is more useful in both social and physical sciences, because the Deductive Paradigm " . . . incorporates a serious misconstruction of scientific activity."[3]

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[1] *Ibid.*, pp. 56-58. For Meehan, "system" and "theory" are synonymous when applied to the physical sciences. "As the term 'system' is defined . . . formal systems perform functions that are usually attributed to 'theories' in the deductive paradigm." *Ibid.*, p. 53.

[2] Dray, *op. cit.*, p. 122.

[3] Meehan, *op. cit.*, p. 4.

> The crux of the argument is that philosophers of science have defined "explanation" mainly in terms of logical properties of scientific theories and their definition ignores other aspects of scientific inquiry--particularly the purposes of inquiry and the use made of scientific theories and explanation--that are just as important as the logical characteristics of scientific explanations. The deductive paradigm assumes that scientists search for general laws that will "cover" particular cases. But the search for "laws of nature" seems part of the rhetoric of science; it has little relevance to scientific practice. What scientists actually do in their work can be construed in other ways. For example, the conception of scientific inquiry adopted here asserts that scientists seek intellectual instruments that permit understanding and control of the phenomena--that control is the central factor in the scientific enterprise.[1]

The notion of a search for intellectual instruments, and the focus upon the goal of inquiry, is quite distinct from an account of the logical structure of the finished product, such as afforded by the Deductive Paradigm.

The approach to explanation given by the System Paradigm, especially the focus upon the process of explaining, is identical with the retroductive account of scientific discovery given by Hanson.[2] In the introduction to his book, Hanson notes that attempts to describe recent particle physics in terms of former paradigms in philosophy of science are doomed from the start:

> If this attitude is accepted, the proper activity for philosophers of physics would then appear to be either (1) to study the logic of the deductive systems which carry the content of microphysics, or (2) to study the statistical methods whereby microphysical theories are built up from repetitive samplings of data. These two approaches may apply to "classical" disciplines. But these are not research sciences any longer, though they were at one time--a fact that historians and philosophers of science are in danger of forgetting. Now, however, they constitute a different kind of physics altogether.

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[1] Ibid.

[2] Norwood Russell Hanson, Patterns of Discovery, op. cit.

> Distinctions which at present apply to them ought to be suspect when transferred to research disciplines; indeed, these distinctions afford an artificial account even of the kinds of activities in which Kepler, Galileo and Newton themselves were actually engaged.[1]

His book, he states, is concerned therefore with the discovery of hypotheses rather than with the testing of them. Thus he describes "not how observation, facts and data are built up into general systems of physical explanation, but how these systems are built into our observations, and our appreciations of facts and data."[2]

The epistemological underpinning of the System Paradigm further shows the emphasis of this paradigm upon the purpose of explanation. (Also, it signals a correspondence with Instrumentalism, a view discussed fully in Chapter IV and used in the analytical scheme itself.) Meehan argues that knowledge is basically organized experience, the organization being effected using mental constructs and concepts. Thus, explanation may be viewed quite clearly as the process by which experience is organized under constructs, and by which these are, in turn, used:

> I am here adopting the point of view called instrumentalism, i.e., the belief that knowledge is only a tool or instrument, hence that it can be evaluated only in terms of its human uses--its value to man. The corollary to that position, which is called nominalism, asserts that the meaning of words lies in the conventions that define their use, and therefore denies that words can have any "essential" meaning, any "real" counterpart in the natural universe. From this point of view, claims to know cannot be judged against absolute truth or unvarying reality because man cannot assert on defensible grounds the existence of absolute truth or unvarying reality. The quality of knowledge depends on the purposes that it will serve.[3]

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[1] *Ibid.*, p. 1. [2] *Ibid.*, p. 3.

[3] Meehan, *op. cit.*, pp. 17-18.

Explanation and knowledge are seen to fulfill two purposes: the need to anticipate events and the need to attempt control over future events. In this light, then, explanations quite clearly cannot be evaluated by the logical criteria required by the Deductive Paradigm. Instead, they are to be evaluated according to whether or not they serve the functions for which they are intended.

This difference between the System Paradigm and the Deductive Paradigm may be exemplified with reference to the concept "entelechy." It has been noted above that "entelechy" was excluded from the class of explanatory concepts by Hempel and Oppenheim.[1] But the Deductive Paradigm cannot both dismiss the concept and account for its longevity in vitalist thought. Viewed from the perspective of the System Paradigm, its longevity is comprehensible: entelechy served the purpose of explaining.

Alternative Attributes of Explanation

Discussion of the Deductive Paradigm revealed that such a way of presenting explanation could lead pupils to think that the only types of explanation that are acceptable are scientific ones. Furthermore, it was demonstrated that since science and explanation are related, such thinking can result in notions of the limitless capability of science to explain.

An alternative picture is provided by the System Paradigm. By focussing on the functional aspects of the process of explanation,

[1]Hempel and Oppenheim, op. cit., p. 330.

different criteria for judging explanations are produced. According to the pragmatic criterion, provided that a set of propositions serves the explanatory function intended, that set is considered as an explanation. Also, explanations presented according to the System Paradigm allow for considering and/or recognizing the limitations of scientific explanations, and thus of science.

Arguments in the section immediately following demonstrate that science is limited as a way of explaining. Arguments in the final section of this chapter show the importance of such a recognition.

The Limitations of Science as a Way of Explaining

Arguments to show that science is limited as a way of explaining come from considering the legitimacy of other ways of explaining, and the place of science in efforts to explain. Two points are revealed below: first, science can be thought of as competing with other ways of explaining and, second, science cannot adequately explain all of the phenomena human beings have to cope with.

Anthropologists, such as Malinowski, have documented the practices used by so-called "primitive" societies, in coping with a variety of phenomena. For example, Malinowski describes the Melanesian use of fairly sophisticated agricultural methods based on systematic thinking and informed by factual evidence. Yet, as a guarantee against the interference of uncontrollable conditions detrimental to their crops, these people freely make use of magic.[1]

[1] Bronislaw Malinowski, Magic, Science and Religion and Other Essays (New York: Doubleday, 1954). See especially pp. 28-29.

As indicated by the title of Malinowski's book, he was examining and comparing three cultural institutions developed by man: magic, science, and religion. The features of science which distinguish it from the other two cultural institutions can be discovered in part, at least, by considering the attributes of constructs invoked for the purpose of explanation, and the resulting explanations themselves. For instance, animism, the willful behavior of inanimate matter, and the interference of omnipotent deities have no place in scientific explanation, yet these constructs are used as a matter of course in magical and religious explanation. The significance of this point is that scientific explanation ie either complementary to, or in competition with, magical and religious explanation. Whichever is the case, science would appear to have definite limitations which are more fully revealed when one considers the function and place of explanation in human experience.

Science as an "Explanatory Mode"

Considerations of this sort are the subject of a recent paper by Roberts, in which he proposes that magic, science, and religion be thought of as three distinct "explanatory modes" ("mode" being used in the statistical sense).[1] Roberts notes that increasing disenchantment with science is evidenced by the growth of the "anti-science movement" and the "counter-culture," as well as by declining enrollment in non-required science courses in universities and secondary schools. This

[1]Douglas A. Roberts, "Science as an Explanatory Mode," Main Currents in Modern Thought, XXVI (May-June, 1970) pp. 131-39.

disenchantment might be explained, he argues, as the result of misrepresentation of science to the young (as an all-embracing way to explain), or else as a result of actual limitations of science perceived by the young themselves. In order to point up such limitations, Roberts makes use of a concept of "myths of science" (a seemingly paradoxical phrase), in the sense that Schorer uses the term "myth": "A large controlling image that gives philosophical meaning to the facts of ordinary life."[1] Thus, "myth" is being used not in the sense of "fantasy," but in the sense of "belief." (Toulmin has made this same use of the term in his paper "Scientific Theories and Scientific Myths."[2])

Roberts defines the "Fundamental Myth of Science" as follows: "Explanation, prediction and the implied possibilities for control of phenomena constitute a useful, meaningful and sufficient way to cope with experience."[3] In his concept of "explanatory mode," the mythology is but one of three structural features of the mode, the others being the "explanatory corpus" consisting of statements of explanation, and a philosophy which is intended to reveal how explanatory statements within the corpus are meant to function. But it is in examining the mythology of the scientific explanatory mode that limitations of science are

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[1]Mark Schorer, "The Necessity of Myth," in Myth and Mythmaking, ed. by Henry A. Murray (New York: George Braziller, Inc., 1960), p. 356.

[2]In Stephen E. Toulmin, Ronald W. Hepburn, and Alistair MacIntyre, Metaphysical Beliefs (London: SCM Press Ltd., 1970), pp. 3-15 (first published in 1957).

[3]Roberts, "Science as an Explanatory Mode," op. cit., p. 132.

revealed. For example, Roberts notes Weaver's point that the institution of contract is not scientific, yet it has contributed enormously to people's capability to cope with experience.[1] For Roberts, this point demonstrates a limitation of science.

> The institution of contract is a "kind of thing" which is beyond the influence of explanation and prediction. A person who thoroughly adopts the fundamental myth of science is apt to be puzzled by institutions centered around the "rights" of people. Yet we need them, in order to establish limitations which prevent us from treating one another as "phenomena"--to be explained, predicted and controlled.[2]

The inadequacy of science being shown here is, it is claimed, " . . . but a reflection of the inadequacy of _explanation_ as a way to cope with experience."[3] This inadequacy is further illustrated by Roberts' interpretation of Malinowski's account of the Melanesians' practices, noted above: after careful application of their agricultural knowledge, they appeal to magic to forestall noxious insects and poor weather. Roberts' interpretation is that the Melanesians are coping with their own anxiety, rather than anything to do with agriculture, as a result of their inability to control certain phenomena. Coping with anxiety in this fashion is not acceptable to the scientific explanatory mode, although it is to the magical mode.

Competition among "Explanatory Modes"

The reference to Roberts' argument illustrates a limitation of

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[1] Warren Weaver, "Science and People," in _The New Scientist_, ed. by Paul C. Obler and Herman A. Estrin (Garden City, New York: Doubleday and Company, Inc., 1948), pp. 48-49.

[2] Roberts, _op. cit._, p. 136.

[3] _Ibid._, p. 137.

science as an explanatory device and indicates an area, namely the use of rituals to cope with anxiety, in which people used science complemented by another explanatory mode. The following argument, relying upon a paper by Peter Winch, is an example of an interpretation that the scientific explanatory mode (to use Roberts' term) is in competition with other explanatory modes, and that it is not possible to judge an explanation from the explanatory corpus of one mode to be better than, or more truthful than, an explanation from the corpus of another. To make this type of judgment, unless it is clear that one of the proposed explanations simply fails to explain, requires the imposition of a value for the appropriateness, correctness, etc. of one explanation over another which is not evident from the explanations themselves. (It is rather a part of the mythology of the explanatory mode.)

Winch's paper initially criticizes an argument by Evans-Pritchard, concerning Azande practices, in which "savage thought" about rainfall is classed as unscientific since it is not in accord with reality. Also, such thought is held to be mystical because it relies upon the existence of supra-sensible forces.[1] The issue is not whether or not Evans-Pritchard is correct in judging Azande thought unscientific and mystical, for it is quite properly described in that way. Instead, Winch is concerned with the manner in which that judgment is made, namely, by suggesting that Azande thought is not in accord with reality.

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[1]Peter Winch, "Understanding Primitive Societies," American Philosophical Quarterly, I (October, 1964) pp. 307-324. Evans-Pritchard's arguments are analyzed in the first section of the paper entitled, "The Reality of Magic."

The problem with this judgment is that Evans-Pritchard has assumed that reality is described, and can only be described, in accordance with the findings of science. Having assumed the conclusion, he has begged the question. Within the System Paradigm the fact remains that phenomena associated with the weather can be explained either scientifically or mystically, and, so long as the proposed explanations account for the phenomena, one is not justified in finding one explanation better or more accurate than the other.

Summary

So, it is quite legitimate to construe science as limited in at least two significant ways. First, science as a way of explaining is limited, since there are aspects of human experience that are "beyond the reach of explanation and prediction," such as the institution of contract. Second, science can be seen as competing with other explanatory modes, whose effect in explaining is the reduction of anxiety about the unknown. And, to maintain that magical or religious explanatory modes are irrational is to _assume_ that rationality and "reality" are definable only in terms of science which, as noted earlier, begs the question.

Consequences of Different Ways to View Scientific Explanation

The rationale for investigating views of science provided in science teaching discourse is established in this section. Drawing upon distinctions already made in this chapter, the analysis below derives logical implications from each way of viewing scientific explanation,

and shows how these implications are of fundamental importance to pupils. As with the analysis of the text excerpt in Chapter I, consequences to pupils are discussed from the assumption that science or scientific explanations are presented in language that is understood in an "ordinary language" context.

Science and Rational Thinking

Quite different implications come from presenting science as _the_ way to explain phenomena (as in the Deductive Paradigm) rather than as _a_ way to explain phenomena (as in the System Paradigm). The first view implies that all other ways of explaining the world are either false or quite unacceptable from the start. Consequences of this view relate to specific understandings pupils can derive about the way in which the world is perceived, and about the intellectual sophistication of those using other ways to explain. From Winch's argument,[1] it follows that this interpretation of science carries with it the notion that the world is organized in a way that can be understood only by scientific thinking. This point of view has been shown to embody a notion of rationality that becomes closely linked with the scientific explanatory mode. Automatically then, one is obliged to call those who rely upon alternative explanatory modes "irrational." The resulting understanding for pupils can be that "primitive" societies are primitive in that they have not attained scientific rationality.

But the use of explanatory modes other than science is not restricted to so-called "primitive" societies. Piaget, for instance,

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[1]Winch, _op. cit._

produces overwhelming evidence that the thought of young children is characterized by animism and other magical explanatory principles.[1] So, the notion that only scientific explanations are rational can have added impact for pupils, especially for those who personally prefer to explain their experiences in magical or religious ways. Such pupils might have difficulty in coping with science teaching which leads them to understand that magical or religious explanations are irrational and/or unacceptable ways of explaining.[2]

Since the System Paradigm allows explanations to be judged according to their usefulness (in explaining what they are intended to explain), implications and potential consequences for pupils are quite different from those stated above. For example, societies employing magical explanations can be seen merely as finding them useful for the intended purpose--explanation. Likewise, personally preferred ways of explaining (religious, magical, or otherwise) can be seen as legitimate ways of coping with experience, so long as they do indeed _explain_ satisfactorily. So the view of explanation provided in classroom discourse can influence how pupils view personal explanation; teaching could be seen as offering implicit or explicit support or rejection for explanations other than scientific ones.

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[1]Of Jean Piaget's many works, the following are particularly rich with examples of children using magical explanations: _The Language and Thought of the Child_ (London: Routledge and Kegan Paul, 1959) and _The Child's Conception of Physical Causality_ (New York: Harcourt, Brace and World, Inc., 1930).

[2]The System Paradigm permits magic and religion to be viewed as rational, internally consistent _systems_.

Representation of the Processes of Science

The criteria for judging explanations are important for the impact each can have upon a pupil's understanding of the way that science functions. In the System Paradigm, for instance, the criterion for judging an explanation has to do with its adequacy. If pupils are provided with this criterion, then they can see that science proceeds by generating explanations and then abandoning them when they fail to account for novel phenomena. Thus, explanations presented in language which corresponds to the System Paradigm allow pupils access to the intellectual processes of the discipline.

Such an understanding of the way that science functions might be preempted by presenting explanations in terms of the Deductive Paradigm, for two reasons. First, as has been noted, the Deductive Paradigm simply fails to take account of how explanations are derived, focusing instead on their logical structure once they have been derived. Second, if the criterion of truth is understood in an "ordinary language" context, then pupils can understand that scientific explanations are found to be true in a literal or absolute sense. This implies that explanations which are no longer used in science were discarded because they were found to be false, rather than inadequate. Accordingly, a quite different picture of the processes of science is implied by the Deductive Paradigm. And it is clear that the way in which scientific explanations are presented in science teaching can provide for quite different understandings about the nature of scientific inquiry.

There is a corollary to this point, for views of science clearly imply views of the history of the discipline. If past explanations are

understood to be false, then pupils can derive the notion that achievements in the history of the discipline are but crude and inaccurate ways of explaining the world. The System Paradigm, however, allows for the realization that previous explanations simply failed to explain adequately phenomena which later became evident.

The "Truth" of Explanations

There are further differences in one's view of science that can be the consequence of how one understands an explanation to be judged acceptable. These differences, it will be seen, are very similar to ones revealed when the text excerpt was analyzed in Chapter I. If, for example, pupils understand the criterion of the Deductive Paradigm that the general law be true in an "ordinary language" context, then as argued before, science can be interpreted as applying absolute explanations. Further, since such explanations are understood as true now, science's inquiries into certain events are final and complete. Thus, this sort of understanding about explanation logically preempts an openness to novel explanations for the same events.

But such consequences as these cannot be derived logically from presentations about explanation which are given in terms of the System Paradigm. The condition for judging explanations in the System Paradigm concerns the adequacy with which explanations fulfill intended functions; thus, one would speak in terms of usefulness, rather than truth. This way of speaking logically allows for pupils to understand that current scientific explanations are accepted because they account for phenomena thus far. And this does not prevent a pupil from realizing that a

currently acceptable explanation may be discarded at a later time, if it fails to account for newly found phenomena.

All the above arguments show clearly that the language in which explanations are given in science lessons (and the context in which the language is understood) can provide pupils with very significant understandings about science. Two further sorts of consequences need mention: understandings about the limitations of science, and understandings about "reality."

There seem to be grounds for suggesting that science teaching can influence how pupils might come to regard the potential of science. If science is presented as a means for usefully explaining phenomena, then provision is made for the recognition that some phenomena, such as the institution of contract, cannot be addressed by science. But a quite different view of the matter can result from teaching which conveys the notion that science provides "true" (in the "ordinary language" context) explanations of "reality," for this can be taken as implying a position similar to Evans-Pritchard's: "reality" is defined in terms of what science can say about the world.[1] So far as logical consistency is concerned, a commitment to this stance requires one to deny that there are phenomena not explainable by science. So no provision is made for recognizing that science is limited when explanations are presented in terms of "true" explanations of the world. Yet, the System Paradigm allows for this sort of recognition, since explanations are presented

[1]Discussion of Evans-Pritchard's position appears in Winch, op. cit., and above (pp. 68-69).

as useful for talking about the world.

For the investigator, the fact that ways of presenting science can influence the way "reality" is perceived has added significance. As Roszak demonstrates, current society can be characterized in terms of a commitment to a stance similar in some respects to that evident in Evans-Pritchard's discussion of Azande practices. Roszak argues the point in terms of what he calls the "Myth of Objective Consciousness."[1] According to this myth, science is the only reliable and respectable way in which true knowledge about states-of-affairs can be obtained. And, he argues, the rejection of this myth by contemporary youth can be seen as constituting both the origin and appeal of the so-called "counter culture." Since Roszak's "Myth of Objective Consciousness" has evident connections with how one views science (whether as a way, or the way of explaining phenomena, or as defining or explaining "reality"), it seems particularly urgent to investigate what views about science are being provided in science teaching.

Summary

Arguments in the previous section establish the importance of investigating views of science provided by science teaching. These arguments were derived from examining different ways of viewing scientific explanations, and then from analyzing the potential consequences for pupils of the two views: the Deductive Paradigm and the System Paradigm.

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[1] Theodore Roszak, The Making of a Counter Culture (New York: Anchor Books, 1969), especially Chapter vii, "The Myth of Objective Consciousness."

For this investigator, the types of consequences revealed above provide adequate support for the contention that an investigation into views of science provided by teaching is fundamentally important.

The purpose of the following chapter is to develop a means for detecting, in classroom discourse, that language which logically provides for intellectual consequences noted in the above arguments. The identification and conceptualization of such language is the basis for the first category of the analytical scheme. The consequences described above are returned to in the next chapter, in order to show how the first category of the scheme makes logical connections between the meaning of words in teaching, and potential consequences of that meaning.

CHAPTER IV

THE STATUS OF THEORIES AND "SCIENTIFIC OBJECTS"

Arguments in Chapter III established the importance of investigating views of science implicit or explicit in science lessons. The logical implications of two ways in which explanation can be construed were shown to provide significantly different consequences for pupils. The purpose of the present chapter is to produce a conceptualization by which the language of classroom discourse can be identified as providing for such differing consequences. This conceptualization can then be used to analyze science teaching.

The conceptualization developed below is derived from Nagel's account of two distinctive ways in which the status of theories and "scientific objects" are viewed: Realism and Instrumentalism.[1] These two views are particularly suitable for this study for two reasons. First, each uses distinctive language to describe what is meant by a theory and a "scientific object." Second, since the study is concerned with the meaning of classroom discourse for pupils, what is said can be identified as representing either Realism or Instrumentalism. So, features of each view become "clues" for identifying the view of science provided in teaching. These "clues" constitute the first category of

[1] These views and their properties are taken from Ernest Nagel, The Structure of Science, op. cit. The analysis below relies especially upon Chapter vi, "The Cognitive Status of Theories," pp. 106-52.

the analytical scheme, "Category 1: View Of Science Provided For."

The present chapter thus presents arguments which establish the first category of the analytical scheme. First, it is necessary to make a distinction between theories and natural laws. In so doing, it becomes clear that the analysis of views about the nature of science has to be restricted so that issues, such as the existence of an independent reality, can be discounted for purposes of this study. This limit to the range of the analysis, and consequent limits to the scope of the study, are discussed in the second section. Next Nagel's accounts of different views about the status of theories and "scientific objects" are examined in detail. Although this study uses two views, Nagel presents three. But, as is argued below, the distinctiveness of the third view, Descriptivism, lies in an issue that has no significant influence on views of science evident in classroom discourse. Accordingly, Descriptivism is discarded for purposes of this study.

Once Realism and Instrumentalism have been described, the suitability of these views for identifying the provisions of science teaching is illustrated by analyzing excerpts from two science lessons. As before, the analysis reveals what <u>can</u> be derived from the discourse if it is understood in an "ordinary language" context. In this portion, the investigator draws upon the logical consequences discussed in Chapter III to show how the view of science conveyed in teaching provides significant consequences for pupils.

As a result of this analysis, features of Realism and Instrumentalism which have potential for identifying classroom speech are listed as alternative items corresponding to one or the other view of

science. The list comprises the first category of the analytical scheme.

Laws and Theories

Nagel distinguishes experimental laws from theories by describing laws as consisting of statements of relations between observable and experimentally determinable traits, whereas theories characteristically do not relate two or more observable traits but consist of a number of statements containing assumptions utilized to explain traits recognized in experimental laws. Thus, for example, the statement containing a relation between the pressure and volume of a gas is an experimental law--Boyle's Law--because the traits "pressure" and "volume" are either experimentally determinable or themselves are described by " . . . an overt observational or laboratory procedure."[1] However, if this relationship is explained in terms of the energy of molecules and their vibrations, the statements of this explanation do not link observable traits, but rather provide a means for comprehending the relationship given in the experimental law.

> Thus, although the theoretical terms "electron," "neutrino," or "gene" may be construed as "particles" possessing some (though not necessarily all) of the properties which characterize small bits of matter, there are no overt procedures for applying those terms to experimentally identifiable instances of the terms.[2]

A feature of experimental laws is that they have a constancy not shared by theories. Nagel illustrates this claim by reference to the Millikan oil drop experiment, and demonstrates that the law will hold independent of the fate of the electron theory:

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[1] Ibid., p. 84.

[2] Ibid., p. 85

> Nevertheless, the truth of the experimental law that Millikan helped to establish (namely, that all electric charges are integral multiples of a certain elementary charge) is not contingent upon the fate of the theory; and, provided the direct observational evidence for it continues to confirm the law, it may outlive a long series of theories that may be accepted in the future as explanations for it. On the other hand, what is said to be an electron is stated by a theory in which the word "electron" occurs; and when the theory is altered the meaning of the word undergoes a modification.[1]

The final distinction made is that experimental laws are single statements, whereas theories are systems of several related statements. This point leads Nagel to the observation that theories, having greater generality, have relatively more explanatory power than do experimental laws.

There is, then, a difference in kind between experimental laws and theories although they perform the same function of explanation. For example, the observation that two solid objects of precisely equal volume have different weights may be explained by reference to their different densities, this explanation relying upon the experimental law stating the relationship between the experimentally determinable traits "density," "weight," and "volume." If a further explanation is sought, one would presumably resort to the atomic theory and its postulates concerning mass and number of atomic particles. These, Nagel would claim, are not experimentally determinable. He admits that the distinction between experimental law and theory relies upon the meaning attached to the word "observable," and is consequently imprecise. The following section is addressed to this difficulty in an attempt to

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[1] Ibid., p. 88.

define the limits of the analysis undertaken here.

A Limitation of the Analysis

To this point, no explicit definitions have been given of terms such as "real," "phenomena," "observable" and the like, for the purpose of the arguments so far has been to elucidate differences in view, rather than to adopt one view in favor of another. Nevertheless, pursual of this course of action can lead to difficulties, one of them being the likelihood of never achieving the intended goal, namely, the development of a scheme for analyzing lessons. Accordingly, it seems justifiable at this point to assume that there is an external reality which has existence independent of our knowledge of it. This external reality, then, contains objects which may be identified by us, such as tables and pencils--the common-sense objects of perception, as they are sometimes called--which are sensible. If one assumes this, then the term "phenomena" refers to attributes of the external world which are perceived by the senses; they are consequently observable.

This assumption appears justified by the purpose of these arguments, which is to examine ways in which science is presented in classrooms, since science itself has been described as <u>a</u> (or <u>the</u>) way of explaining the world. Thus the concern is not with the question of the existence of an independent reality, rather it is with how knowledge of this assumed independent reality is represented to pupils. Furthermore, descriptions of different views of scientific theories and "objects" which invoke the question of the existence of an independent reality seem to be doing more than presenting accounts of how theories and

"objects" might be viewed. Indeed, instead of presenting accounts of the knowledge we have, such descriptions would include arguments to prove whether or not the external world is potentially knowable and how it can be known. The latter arguments would constitute a thesis on perception, which is beyond the scope of this study.

The position adopted here (that there is a reality whose existence is independent of our knowledge of it) has been called in some places, "realism." This particular use of the term "realism," however, is distinct from its usage in this study. For present purposes, "Realism" (with a capital letter) denotes the view that "scientific objects" which are not directly observable have an existence in reality equal to that credited to the common-sense objects of perception. This position and others are examined in the section immediately following.

The Status of Theories

Nagel identifies three separate views on the cognitive status of theories: the Realist view, the Instrumentalist view, and the Descriptivist view.[1] In the following account no attempt is made to judge among them, since the study is not concerned with judging teaching; instead, the distinguishing features of each position will be extracted in order

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[1]The purpose of using capital initial letters for these terms is given on pp. 10-11, above. Capitals are used consistently for Nagel's terms and for the terms developed in this study.

that these can be identified within teaching discourse.

The Realist View

Briefly, the Realist view describes theories as statements having the property of being either true or false. Also, the terms signifying "scientific objects" in these statements refer to alleged objects in the external world. So, "scientific objects" such as "atoms," etc., are accorded a reality status precisely equal to that accorded to common-sense objects of perception.

Nagel notes that a number of difficulties ensue from adhering to this position. The examination of these is pertinent to the present task. First, Nagel claims that, " . . . theories are commonly formulated in terms of limiting concepts which characterize nothing in existence, so that at any rate non-vacuous factual truth cannot be claimed for such theories."[1] Nagel exemplifies this point with reference to velocity:

> For example, we can attribute a velocity to a physical body only if the body moves through a finite, non-vanishing distance during a finite, non-vanishing interval of time. But instantaneous velocity is defined as the limit of the ratios of the distance and time as the time interval diminishes toward zero. In consequence, it is difficult to see how the numerical value of this limit could possibly be the measure of any actual velocity.[2]

This criticism is averted, it is alleged, either by claiming that the differences between "ideal" traits of the theory and those determinable by experiment are negligible and may be ascribed to experimental error, or by suggesting that the inaccessibility of such limiting notions to

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[1] *Ibid.*, p. 142. [2] *Ibid.*, p. 131.

measurement does not disprove their existence which, on the contrary, is supported by a considerable amount of evidence.

The second difficulty, Nagel notes, is that, ". . . apparently incompatible theories are sometimes employed for the same subject matter. Thus a liquid cannot be both a system of discrete particles and also a continuous medium, although theories dealing with the properties of liquids adopt one assumption in some cases and the opposing assumption in others."[1] Nagel gives two Realist rejoinders to this criticism. The first consists in pointing out that although seemingly incompatible, the one theory is merely a simplification of the other, and the simpler theory is then to be regarded as a special case of the more complex one. The second rejoinder is that incompatible theories are makeshift arrangements to be abandoned when a more comprehensive theory including the makeshift ones is developed.

The final noteworthy difficulty results from the interpretation of quantum mechanics in which electrons, it is postulated, are credited with apparently incompatible characteristics:

> Thus, electrons are construed to have features which make it appropriate to think of them as a system of waves; on the other hand, electrons also have traits which lead us to think of them as particles, each having a spatial location and a velocity, though no determinate position and velocity can in principle be assigned simultaneously to any of them.[2]

Nagel shows that rejoinders to this criticism of the Realsit view (that electrons are given incompatible properties) parallel rejoinders to the previous criticisms. For instance, the absence of "visualizable models"

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[1] _Ibid._, p. 143.   [2] _Ibid._, p. 144.

for quantum mechanics is insufficient grounds for denying that quantum theory " . . . formulates the structural properties of subatomic processes."[1] Also, it may be that a theory will be formulated to include both sets of characteristics of the electron.

The Instrumentalist View

The interpretation of theories as logical instruments, which is the central claim of the Instrumentalist view, evades the difficulties encountered by the Realist view. Nagel presents the Instrumentalist premise as, "A theory is held to be a rule or a principle for analyzing and symbolically representing certain materials of gross experience, and at the same time an instrument in a technique for inferring observation statements from other such statements."[2] Accordingly, incidences of apparently incompatible theories are of no consequence, for both theories are seen as conceptual devices for handling similar phenomena. In addition, no problems arise with the notion of limiting concepts, for they are seen as devices for simplifying theoretical statements. Furthermore, the applicability of theories to what is observed is determined by scrutinizing usefulness rather than by determining their truth or falsity, or (for "scientific objects") their existence in the real world.

Nagel notes that there is no uniform account of "scientific objects" given by proponents of the Instrumentalist view. His argument indicates that consistency with this view commits one to denying the

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[1] Ibid.

[2] Ibid., p. 129.

physical existence of postulated entities (scientific objects) contained within theories:

> For if a theory is just a leading principle--a technique for drawing inferences based upon a method of representing phenomena--terms like "electron" and "light wave" presumably function only as conceptual links in rules of representation and inference. On the face of it, therefore, the meaning of such terms is exhausted by the roles they play in guiding inquiries and ordering the materials of observation; and in this perspective the supposition that such terms might refer to physically existing things and processes that are not phenomena in the strict sense seems to be excluded.[1]

For this reason the Instrumentalist view will be taken as positing no absolute existence to "scientific objects" contained within theories.

The Instrumentalist view is not without difficulties. For example, there is no reason, Nagel contends, to maintain that since theories function instrumentally they cannot be characterized as true or false. This problem, it is admitted, is purely formal. That is, it is one of deciding whether or not the sentences of a theory may be considered as having statement form and thus as being true or false. But there is a further connected problem which results from noting that a theory may be used as a leading principle in one context and as a premise in another. Both problems may be exemplified as follows. In the argument stating that "x is P" is derived from the premises "All S are P" and "x is S," the leading principle permitting the move is the principle of syllogism: it is not dependent on the subject matter terms contained in the premises. But the argument may be reformulated to state that "x is P" is derived from "x is S," in which case the leading principle is, "Any statement of the form 'x is P' is derivable from a

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[1] Ibid., p. 140.

statement of the form 'x is S'." This leading principle is material in that it is dependent on the subject matter of the terms. The latter principle may be considered as a theory, and so may the former (i.e., the principle of syllogism). Nagel argues, then, that it is of no consequence how the theory is used in the argument, since most arguments, he claims, may be written in either form. However, a further objection to this view, Nagel notes, is that theories are usually used by scientists as premises rather than as leading principles, investigations being undertaken " . . . on the assumption that a theory is a projected map of some domain of nature, rather than a set of principles of mapping."[1] Indeed, much scientific research, it is claimed, is aimed at providing evidence for or against a theory which is a futile endeavor if theories are neither true nor false. The rejoinder to the above criticisms is that:

> . . . it is sufficient to reply that a theory can indeed be "tested" by searching for evidence which will either "confirm" or "refute" it, but only in the sense that confirmatory or disconfirmatory evidence is sought for observational conclusions drawn from observational premises in accordance with the theory. As we have seen, the sole issue raised by this way of putting the matter concerns the relative convenience of employing material rather than purely formal leading principles in reconstructing deductive inferences.[2]

A final difficulty remains with the Instrumentalist view, namely that it " . . . precludes its adherents from admitting the 'physical reality' (or 'physical existence') of any 'scientific objects' ostensibly postulated by a theory,"[3] when many scientists proclaim their conviction of the existence of atoms and the like. Nagel finds

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[1]Ibid., p. 139. [2]Ibid., p. 145. [3]Ibid.

resolution of this difficulty hindered by the many extant meanings of the term "reality." Within the context of the present analysis, "real" corresponds to "observable." Thus, despite the accumulation of indirect evidence for the existence of such "scientific objects," the consistent Instrumentalist view, in which such existence is denied, is a legitimate view of theories.

The above discussions have revealed then that there are two quite feasible views of theories proposed by philosophers of science, which are independent of what scientists themselves either say or do. These alternative views may be summarized, for present purposes as follows:

> Instrumentalist view: theories are conceptual devices, being neither true nor false; the "scientific objects" of theories are theoretical entities and do not have an existence in the external world.
>
> Realist view: theories are statements which are either true or false; the "scientific objects" in such statements exist in reality.

The Descriptivist View

Arguments in the previous chapter distinguished between science as _a_ way (or _the_ way) of explaining the world, and science as describing the world. But the focus on explanation in the previous chapter, as acknowledged then, preempted any consideration of the view that science describes. This view is now examined in more detail, and the argument demonstrates that it may be discounted from the present study for two reasons. First, it contains a thesis about perception and therefore falls outside the scope of the current analysis. Second, the status of theories and "scientific objects" as presented in Nagel's account of the

Descriptivist view can be seen as identical to the status accorded them by either one of the other two views, depending on the outcome of an argument undertaken later.

The Descriptivist view discussed here is not concerned with the description of phenomena (which are observable) prior to their explanation, but rather with the claim that scientific theories are simple or economical statements of what is seen to occur. This distinction is exemplified as follows. If an electrical circuit containing a battery, a light bulb and a meter is connected, then the statement "The needle of the meter is pointing to .30 amps." is a description of phenomena. However, the statement, "The current in the circuit is .30 amps." assumes (electrical) current theory and therefore is not a straightforward report of phenomena, according to the Instrumentalist view. (In fact, an Instrumentalist account of the observation might well indicate that "current" is a theoretical construct whose postulation enables one to link certain observable traits of the circuit, such as needle movements, and thereby explain them.) A proponent of the Descriptivist view, it seems, would hold that the second statement, like the first, is a description of the world; the term "current" is thus viewed as an abbreviation meaning all phenomena in similar, prescribed circumstances.

Nagel notes that the Descriptivist view can be seen as a halfway position between the Instrumentalist and Realist views, and he summarizes its claims thus:

> According to it, a theory is a compendious but elliptic formulation of relations of dependence between observable events and properties. Although the assertions of a theory cannot be properly characterized as either true or false when they are taken at face value, a theory

> can nevertheless be so characterized insofar as it is translatable into statements about matters of observation. Proponents of this position usually maintain, therefore, that in the sense that a theory (such as an atomic theory) can be said to be true, theoretical terms like "atom" are simply a shorthand notation for a complex of observable events and traits, and do not signify some observationally inaccessible physical reality.[1]

He isolates two versions of the Descriptivist view, the first of which he holds to be a consistent extension of phenomenalist epistemology, by which " . . . the psychologically primitive and indubitable objects of knowledge are the immediate 'impressions' of 'sense contents' of introspective and sensory experience."[2] Accordingly, all objects, whether they are hypothetical or physical, are defined in terms of immediate sense contents. Thus, all empirical statements not containing expressions of sense contents must be translatable without loss of meaning into statements concerning these alleged immediate objects of experience. The second version, designated by Nagel as less radical, accepts "ordinary gross experience" as the starting point for its analysis, and claims that " . . . all theoretical statements are in principle translatable, again without loss of meaningful content, . . . into statements about the observable events, things, properties, and relations of commonsense and gross experience."[3] Central to both versions of the Descriptivist view, then, is the thesis of translatability of theoretical statements. The distinguishing feature of the first version may be discounted here, for it invokes a thesis about perception utilizing the notion of immediate sense contents. This distinction is found irrelevant because the present argument is concerned with how the world is represented

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[1]*Ibid.*, p. 118. [2]*Ibid.*, p. 120. [3]*Ibid.*, p. 121.

once it has been perceived.

The remainder of Nagel's account of the Descriptivist view is devoted to attacking the translatability thesis which is concluded by the judgment that the view is untenable. The details of his criticism need not be mentioned here, for the present concern is to determine how the view might be represented, rather than attacked. So it is useful to refer to the way in which Nagel finds the view might be represented. He notes that a distinction is sometimes made between abstractive and hypothetical theories, the former " . . . formulating relationships between properties common to classes of objects of phenomena 'perceived by the senses' . . ."[1] but excluding anything hypothetical or conjectural (which is the characteristic of the latter group). These types are discussed in some detail and it is argued that both types of theory depend upon the thesis of translatability. His conclusion is significant:

> Accordingly, abstractive and hypothetical theories are in the same boat, as far as their translatability into the language of observation is concerned. In any event, no one has yet succeeded in showing how either type of theory can be so translated, even in principle; and the translatability thesis remains for both of them, not a description of the established nature of any actual theory but a highly debatable program for analyzing theoretical statements. It follows that, on the view concerning the cognitive status of theories which we have been considering, truth and falsity cannot properly be predicated of any current physical theory--at least not until its alleged translatability into observational language is established. In effect, therefore, the view under discussion coincides with the second position mentioned earlier, according to which theories are best regarded as statements about which questions of truth and falsity can be usefully raised.[2]

Here Nagel has in discounting the translatability thesis accorded theories as described by the Descriptivist view a status similar to that

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[1] _Ibid._, p. 125.

[2] _Ibid._, pp. 128-129.

enjoyed by theories according to the Instrumentalist view. However, if such a translatability is proven feasible, then the status of theories is similar to that enjoyed by theories as described by the Realist view.

Consequently, whatever the outcome of this philosophical debate, it is sufficient to classify the status of theories and "scientific objects" according to two views only, the Instrumentalist view and the Realist view. Both these views represent the nature of scientific theories. They do not depend upon any thesis concerning how perceptions are received, and both rest upon the assumption that there is an external reality independent of ourselves, about which we can have knowledge.

The Significance of Realism and Instrumentalism

The previous section shows that two quite different views of the nature of science are conveyed by speaking differently about theories and "scientific objects." For Realism, theories are spoken of as either true or false statements, and "scientific objects" as having an existence in reality. For Instrumentalism, theories are useful conceptual devices, and "scientific objects" are theoretical entities with no existence in reality. Since each way of speaking presupposes one or the other view, the speech in science teaching can do the same. Teaching which conveys the meaning that theories are true or false, and/or that "scientific objects" exist in reality, provides for the Realist view, and for all the logical implications of that view. Similarly, teaching which conveys the meaning that theories are useful conceptual devices (to account for phenomena), and/or that "scientific objects" are theoretical entities, provides for the Instrumentalist view, and for all the logical

implications of that view.

So, the significance of the two views for this study is that they yield straightforward "clues" by which one can identify the view of science provided in classroom discourse. (The significance of detecting this sort of provision was established in Chapter III.)

In the following two sections, portions of science teaching are analyzed to show how each can be identified as Realist or Instrumentalist. This identification is achieved by considering that each portion is understood by pupils in the context of "ordinary language." Once the teaching has been identified, arguments show how potential consequences for pupils can be derived logically, these arguments drawing upon distinctions made in Chapter III.

The portions of teaching used below are taken from the twelfth and eleventh lessons respectively in the group recorded and transcribed for this study.[1] The excerpts appearing below are deliberately selected to illustrate Realism (the twelfth lesson) and Instrumentalism (the eleventh lesson).[2] For the investigator, these lessons are particularly

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[1]Not all of the fourteen lessons recorded and transcribed have been used in the study. Portions of the eleventh and twelfth are selected for a specific purpose, as are portions of others. Chapter VI presents the rationale for selecting the <u>whole</u> lessons used in the study.

[2]Although, for present purposes, these extracts are analyzed as if they are understood in an "ordinary language" context, the actual context is established quite clearly from interviews with the respective teachers. Portions of these interviews appear in Chapter VI. At that point, the investigator shows that the context of the twelfth lesson is Realism, and that of the eleventh is Instrumentalism. These portions of interviews may be found in Chapter VI, pp. 167-170.

interesting, for each is an introductory lesson in static electricity, taught to pupils in the tenth grade.

Identification and Consequences of Realist Teaching

The twelfth lesson begins with the teacher asking pupils to give instances of phenomena which are "because of static electricity." There is then some discussion of the differences between static and current electricity, followed by a series of demonstrations. These demonstrations form the major part of this lesson. In turn, the teacher rubs different rods (ebonite and glass) with different pieces of material (fur and silk) and brings each rod up to a suspended pith ball. Pupils predict what will happen, and discuss what they observe.

Immediately below, the notion of charge is presented by the teacher for the first time. (The word has appeared in the lesson twice before, but in each instance, it was used by a pupil.) The teacher has just brought an "un-rubbed" ebonite rod up to the pith ball. Pupils observed no movement.

> Teacher (Performing the demonstration)[1]: Now if we take the ebonite rod and rub it very hard with the fur, what should happen now?
>
> Pupil: It attracts.
>
> Teacher: Does anyone know? Les.
>
> Les: It should attract it
>
> Teacher: It should attract. (There is noise) All right.

[1]Words in parentheses are added by the investigator at the time of transcription. The intent is to make the discourse more comprehensible.

Now, at the moment when I first put (the rod) up there, was there any charge?

Pupils: No. No.

Teacher (Performing the demonstration): See, I put this ebonite rod up, I haven't rubbed it, so what can we say about the charges in the pith ball when nothing happens? I don't want technical terms, I just want you to tell me if you think there's any...any type of charge at all on that, er, pith ball. Peter.

Peter: No.

Teacher: No. We won't use any special name for it right now other than just no charge there. (The demonstrations performed with ebonite and other materials do not reveal pronounced effects; however, effects can be observed.) Now, I've rubbed this with the, er...ebonite rod in the fur...all right now, it attracted it, right? The ball came out and touched it. (The cotton thread suspending the ball breaks; laughter.)

Pupil: You broke it.

Teacher: All right. We'll try it again now...we go through the same procedure again. Now what should happen this time? The first time nothing happened, the second time it was drawn towards the ebonite rod. What should happen this time? (Pause) And also, when it was drawn towards the ebonite rod the last time, it touched it. (There are indistinct suggestions.) All right, Kelly. It always worked before nine (that is, immediately prior to the lesson). Now, if the air is dry--what should happen when I take this...what's happening to the charge on here...what should happen to it in relation to the pith ball? Dave.

Dave: It should repel it after you've touched it once.

Teacher: But the first time it was neutral, so what...before it...if it's going to repel it the next time, what must happen to the charge?

Dave: It's going to be positive.

Pupil: No. Negative, negative.

Teacher: But the pith ball...nothing was happening, it was neutral.

Dave: Well, when you touched it first it sent the charge into the pith ball.

Teacher: All right. Did you hear that?

Pupils: No.

Teacher: Ian, what did he say, er, Paul?

Paul: Er...(some laughter).

Teacher: Could you repeat it, Dave.

Dave: Peter knows (laughter). Er, oh yeah, when you touched it it charged the pith ball.

Teacher: Okay, it charged the pith ball. So something was getting from the ebonite rod over to the pith ball.

This portion of teaching is seen as representing Realism because of the consistent use of the word "charge" in a fashion which suggests that charges have a physical existence. For instance, in line 9, the question understood in an "ordinary language" context implies that one can determine whether or not charges are present. Exactly the same implication is conveyed by the use of "charge" in lines 15 and 18. These statements can be compared with the segment between lines 25 and 32 in which the language speaks clearly of describing observations or phenomena. But, without any explicit signal of a change in context, the teacher then asks, "What's happening to the charge on here . . . " (line 33), as if one were able to observe the charge. Further evidence that "charges" are being spoken of as if they are real is available from line 53. At this juncture, the teacher asserts that something moved from the ebonite to the pith ball.

On this basis, the teaching appears to be identifiable as providing for a Realist view of science. Additional support for this

characterization comes from the manner in which theoretical or explanatory statements are presented as if they are descriptions of the world. For instance, in lines 38-39, the teacher implies that repulsion means that something has happened to the charge. Alternatively, one can consider that the use of "charge" (and associated theories) enables one to explain the phenomenon of repulsion. This distinction can be captured by saying that the theoretical or explanatory statement about charge and repulsion has the same "logical form" as an observation statement. That is, there is nothing in the statement as it appears in lines 38-39 to indicate that it is anything other than a description of phenomena. Similarly, the imperative in lines 14-15 "looks" like (and "sounds" like) an imperative calling for an observation or description such as, "Tell me if you see any snow on the ground." Not only is there no indication that the statement is to be understood differently from an observation statement, but also there is no indication that a theory or explanation is being employed here. Instead, whatever the underlying theory, it is being presented as part of the description of "what's happening." Consequently, this portion of teaching is identified as providing for a Realist view of science, assuming that the discourse is understood in an "ordinary language" context.

The consequences provided for by this portion of teaching can be derived from considering the implications of talking about charges as if they exist, and of presenting theoretical or explanatory statements as descriptions of the world. In the paragraphs that follow, these consequences will be recognized as similar to those derived in Chapter III from presenting explanation according to the Deductive Paradigm.

First, if "charges" have a physical existence, then, logically, there can be no other way of explaining the phenomena presented by the teacher. Accordingly, science has successfully terminated its inquiries in this area. Furthermore, previous attempts at explaining these phenomena using, say, "electrical effluvia," must have been false, presumably because electrical effluvia do not exist. The language of these implications suggests that science proceeds in its endeavors by something akin to an inspection of reality, and that truth for science is a matter of determining what is "really there" in the world.

All these are potential consequences in the form of understandings about science which can be derived from a Realist account of science in teaching. Additional consequences can be derived as in Chapter III. If science has correctly described these phenomena, no other sorts of explanation (magical or religious) can be legitimate. Science then becomes viewed as <u>the</u> means of describing the world, precluding the legitimacy of other ways of explaining. This further implies that science is unlimited in its capacity to explain or describe states-of-affairs.

Because these consequences are logically associated with the Realist view, any mention of them in teaching discourse provides further ways of identifying the view of science <u>provided for</u> as Realist. For instance, a teacher might state that a former theory is false, or that a "scientific object," like electrical effluvia, was found to be an inaccurate account of reality. All these features of Realism, then, are used for two purposes in this study: they are used as logical consequences of teaching which is identified as Realist, and they are used

themselves to identify teaching as Realist. In the final section of this chapter, these features are collected to form part of the first category of the analytical scheme.

Arguments similar to those above are presented in the next section. The difference though stems from identifying the portion of teaching with the Instrumentalist view of science. As noted above, the eleventh lesson presents a very different introduction to static electricity.

Identification and Consequences of Instrumentalist Teaching

In the previous section, the teaching was identified as Realist initially upon the finding that charges were spoken of as if they had a physical existence. The notion of electrical charge is presented quite differently in the eleventh lesson. To show this, the major excerpt below is preceded by two smaller excerpts from the lesson.

At the beginning of this lesson, the teacher rubbed an ebonite rod with wool, and showed how small, light objects jumped around when the rod was brought close to them. During this time, the teacher spoke, and had pupils speak, only about what could be seen (for example, "a rod is cleaned and polished").

> Teacher: And it was kind of an interesting curiosity for a long time--that when you cleaned and polished this piece of amber it had this magical property of being able to cause light little things to jump about...

The teacher has asserted that this "magical property" was first observed for amber. Next, the teacher gives the origin of some contemporary terms:

> 5 Teacher: and the Greek word for amber was that...(writing,

"electron" on the board). So he (unidentified) called materials like this--like the ebonite rod and so forth, the amber--he called them "electrics" (writing "electrics"), or "amber-like materials"--that's where we got the name, from this word that's in here.

There follows a brief discussion of other "amber-like materials," after which:

Teacher: There are other things that people began to notice about the effect. It went away after a while. Although the object might still be clean and shiny, it did go away after a while. It sort of tended to destroy our theory that because it was clean and shiny that these effects occurred. (Pause) People began to think of it as having some property all its own because of the fact that we had done this to it. (The rod is rubbed again, and brought up to pieces of paper.) Performing this operation on the rod that gives it some, some new property that it didn't have before that it could lose. That it somehow needed to be revitalized after a time, or recharged. The use of the term "charging" for "filling something up" is not uncommon. So we came to think of these things as having some kind of property which needed to be recharged, or refilled, or redone periodically. And we came logically after a while to think of it as having initially a charge. Whatever this property was we called it a charge. And since it was an electrical material, it seemed logical to call it some kind of electrical charge. So it's odd sometimes how these terms arise--very odd indeed. These have come more through the language than anything else. There's no logical, er, reason for that to, er... reason to lead us to the fact, "Well, obviously...." Someone was trying to tell us earlier (in this lesson), "Obviously, these are electrical charges or electrostatic charges," or something. These are terms that we didn't have before, and types of thinking that we didn't have before either.

Features of this eleventh lesson which distinguish it so plainly from the twelfth are the teacher's emphases upon the way language is used. Although the investigator assumes that the discourse is understood in an "ordinary language" context, there are many indications to the listener and reader that the language in this portion of discourse is to be understood in a special way. Furthermore, it is clear that the teacher differentiates between two sorts of statements: observation

statements, and theoretical or explanatory statements. Support for both these characterizations is provided below.

"Charge" is introduced in lines 20-27 as a way of thinking about particular properties of similar materials. These materials are identified as "electrics" or amber-like because they exhibit these properties. As the teacher states in line 36, the terms convey quite different ways of thinking, which is quite distinct from suggesting that such terms describe objects found in reality. The emphasis on presenting theoretical or explanatory statements as "ways of thinking," rather than as descriptions, is identifiable with the Instrumentalist view of science. And, that theoretical or explanatory statements differ in type or "logical form" from observation statements is made plain by the signal, in line 23 for instance, that we came to think of these materials in a certain way, not to describe them differently because of what we see in them.

Not surprisingly, once a distinction is made between observation statements and theoretical or explanatory statements, one finds that "scientific objects" are presented as postulated or conceptual entities, rather than as being real. "Charge" is shown clearly to have conceptual origins in lines 20-27. Indeed, the teacher states explicitly that there are no logical reasons for saying that charges are "there" (lines 31-35).

So this portion of teaching contains features resembling the two features of Instrumentalism: theories are conceptual devices, being neither true nor false, and "scientific objects" of theories are theoretical entities that have no existence. This portion of classroom

discourse is thus characterized as providing for the Instrumentalist view of science.

The consequences provided for by this portion of teaching are derived in a fashion similar to that used in the previous section. However, consequences detailed below correspond to those of the System Paradigm, instead of the Deductive Paradigm. Accordingly, potential consequences of teaching identified as Instrumentalist are opposite to those of Realist teaching.

Since "charges" are presented as conceptual, then it follows logically that the electrical phenomena explained by the concepts might be explained in other ways, using different concepts. Science, then, has not necessarily exhausted inquiry into this area. Furthermore, previous attempts at explaining these phenomena can be seen as inadequate, rather than false. So, the implication for understanding how science progresses is that science presents attempts to explain phenomena which involve inventing conceptual devices. The criterion for accepting explanations has to do with their adequacy, not with their truth in the "ordinary language" sense of the term.

Further potential consequences can be derived in a manner similar to that used in Chapter III. Making it clear that explanatory concepts are invented as ways of thinking does not logically preempt the validity or appropriateness of other ways of explaining the world in empirical terms. Accordingly, there is no message here that science is unlimited.

As with features of Realism, features of Instrumentalism can be used to identify this view of science within classroom discourse. For

instance, a teacher might state that former theories were found inadequate and were abandoned consequently. Since this statement follows from Instrumentalism, its presence in science teaching can be used to characterize that teaching as providing for the Instrumentalist view of science.

All the above features of Instrumentalism are collected below to complete the first category of the analytical scheme.

The First Category of the Analytical Scheme

In this chapter, the investigator has shown that distinct views about the status of theories and "scientific objects" imply quite distinct views concerning the nature and limitations of science. Moreover, in the previous two sections, the basic premises of Realism and Instrumentalism have been shown to be useful for characterizing portions of science teaching according to the view of science conveyed explicitly or implicitly by the discourse. Further analysis revealed that, once portions of teaching have been characterized, their potential consequences for pupils can be derived. (Detailed arguments deriving many of these consequences appeared in Chapter III, where their fundamental importance for pupils was demonstrated.)

Logically derived features of Realism and Instrumentalism are presented below in summary form, to establish the first category of the analytical scheme. These features of Realism and Instrumentalism, or "items" of the first category, are alternatives in that they force

statements into one or the other view of science.[1]

The Realist View

Teaching that provides for the Realist view, and for the consequences of that view, will have one or more of the following features:

a. Theoretical statements have the same logical form as observation statements.[2]

b. "Scientific objects" have the same ontological status as common-sense objects of perception.

c. Science is presented as the only acceptable way of describing or explaining the world or phenomena.

d. Science is spoken of as superior to alternative explanatory modes.[3]

e. Past theories are presented as false.[4]

f. Lapsed "scientific objects" given as inaccurate accounts of reality.

g. The potential of science for explaining or describing the world is given as unlimited.

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[1] Later in this study, individual items are referred to as follows: R-a (for "Realist, Item a"), I-a (for "Instrumentalist, Item a"), etc.

[2] The phrase "logical form" is defined above on page 97.

[3] That is, other ways to explain, such as magic, are inferior because science is presented as providing true explanations or descriptions of states-of-affairs.

[4] The phrase "past theories" refers to theories that are presented in teaching as no longer acceptable to the scientific community.

h. The use of a model, law, theory, or convention is not signalled.[1]

i. A model, law, theory, or convention is invoked as a description of phenomena.

The Instrumentalist View

Teaching that provides for an Instrumentalist view of science, and for the consequences of that view will have one or more of the following features:

a. Theoretical and explanatory statements have a different logical form from observation statements.

b. "Scientific objects" have a different ontological status from common-sense objects of perception; they are postulated entities.

c. Science is presented as one way of explaining phenomena.

d. Science is spoken of as in competition with alternative explanatory modes.

e. Past theories are presented as inadequate.

f. Lapsed "scientific objects" are given as inadequate explanatory devices.

g. The potential of science for explaining and describing is given as limited.

h. The use of a model, law, theory, or convention is signalled.

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[1]The terms "model" and "convention" are introduced here since they might legitimately appear in lessons in place of "theory." Signals to pupils might take the form of phrases such as, "We come to think of this as . . . " or "This can be explained by considering . . . ." Importantly, the signal suggests that the statement which follows is conceptual in origin, and is therefore different from a description of phenomena.

i. A model, law, theory, or convention is invoked as an explanation of phenomena.

Summary

The formulation of this first category of the analytical scheme completes the first portion of the theoretical component of this study.[1] By examining different views on explanation and different positions on the status of theories and "scientific objects," the investigator has generated a set of alternative items which is potentially useful for characterizing science teaching according to the view of science presented. In addition, such characterizations allow one to detect the consequences provided for by portions of teaching, and these potential consequences have been shown already (in Chapter III) to be significant for pupils.

In the next chapter, the second category of the analytical scheme is derived. This, as noted in Chapter I, focuses on the provision made by teaching for Intellectual Independence or Intellectual Dependence. Arguments are provided to demonstrate the importance of investigating this way to characterize teaching.

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[1] The analytical scheme derived from these theoretical considerations is reproduced in its entirety in the Appendix, p. A2, and titled, "Initial Analytical Scheme" to distinguish it from the version which results from trials with the theoretically derived items. The first category of the scheme is headed, "Category 1: View Of Science Provided For". In tables accompanying the statistical analysis in Chapter VI, this heading is abbreviated to "Category 1: Realist/Instrumentalist."

CHAPTER V

EPISTEMOLOGY AND THE PHILOSOPHICAL ANALYSIS OF TEACHING

Introduction

Arguments in Chapter IV established the first category of the analytical scheme. Using this part of the scheme, one can detect the view of science provided in teaching, and the potential consequences for pupils implied by that view. As noted in Chapter I, science teaching has potential for important consequences other than the view of science provided. Because science teaching is concerned with knowledge claims about the world, it can provide pupils with understandings of how these claims are supported and judged as acceptable. Additionally, the availability or lack of evidence or argument to support knowledge claims has potential for influencing the extent to which pupils can judge such claims for themselves. Consequences such as these are related to epistemological features of teaching. In this chapter, arguments demonstrate the importance of investigating these features. Then, frameworks are derived for conceptualizing epistemological features of teaching, in a way which allows one to identify their potential consequences for pupils. These conceptualizations become the second category of the analytical scheme.

Conceptualizations used in this chapter have their origins in accounts of epistemology and the philosophical analysis of the concept "teaching." Pertinent features of these two areas are combined later

under the concepts, "Intellectual Independence" and "Intellectual Dependence." In the first section below, the significance of investigating teaching with these perspectives is substantiated by focusing on potential consequences for pupils. The remainder of the chapter is devoted to developing the second category of the scheme. But before this is started, it is necessary to secure the particular uses of the terms "teaching" and "learning," for purposes of this study. Arguments in the second section accomplish this and, at the same time, provide a foundation for conceptual distinctions which are discussed at length in later sections.

Next, Scheffler's account of the traditional conditions of knowledge is presented: truth, evidence, and belief.[1] Here it is shown that a purely epistemological framework is inadequate for present purposes because of problems with the conditions of truth and evidence. Thus, in the fourth section, the notion of Intellectual Independence and Intellectual Dependence is introduced as a way of overcoming problems with the traditional account.

In Chapter I, the investigator argued that the concepts Intellectual Independence and Intellectual Dependence have additional use, because they capture potential consequences of teaching as revealed by philosophical analysis. This property of these concepts is explored in the fifth section. It is shown that while Intellectual Independence

[1]Israel Scheffler's account of the traditional conditions of knowledge is taken from his book, Conditions of Knowledge: An Introduction to Epistemology and Education (Glenview, Illinois: Scott, Foresman and Company, 1965).

corresponds with potential outcomes of certain uses of "teaching," Intellectual Dependence is similar to the potential outcomes of indoctrination.

A separate section is devoted to demonstrating how Intellectual Independence and Intellectual Dependence can be used to incorporate features of teaching which distinguish it from other sorts of social interaction.

The second category of the analytical scheme consists of features of classroom discourse which provides for either Intellectual Independence or Intellectual Dependence. These features, which are derived throughout the chapter, are collected in the last section, and are presented as the second category of the analytical scheme.[1]

The Significance of Intellectual Independence and Dependence

The significance of the consequences Intellectual Independence and Intellectual Dependence is addressed below by considering those features of classroom discourse that these alternative concepts are intended

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[1]It will be seen that detecting the provision made for either Intellectual Independence or Intellectual Dependence does not depend on assessing the meaning that can be derived from classroom discourse, in an "ordinary language" context. Instead, one determines if evidence is provided, or if a pupil's response is or is not treated rationally (to use examples from the second category of the scheme). So, the second category is used differently from the first category. Accordingly, the investigator has not found it necessary to include analyses of portions of teaching in this chapter. Of course, context is still important. One needs to know, for instance, if evidence for knowledge claims was given in a previous lesson. Here, as before, context is established through interviews with teachers. This procedure is discussed and exemplified in Chapter VI.

to capture. Here, then, two specific types of features are discussed: those having to do with the fashion in which knowledge claims are presented, and those relating to ways in which responses of pupils are handled by teachers. In what follows it will be seen that potential consequences of these aspects of teaching can be subsumed beneath Intellectual Independence and Intellectual Dependence, and that these consequences are significant for pupils.

Different Presentations of Knowledge Claims

The significance to pupils of different ways of presenting knowledge claims is readily demonstrated by considering two distinct ways. In the first case, a claim about the world might be presented together with evidence and argument that show why and how that claim is accepted. When these are present, pupils can decide upon the truth of a claim for themselves. If relevant information is present, pupils can make judgments about knowledge claims in a fashion that is independent of the authority of their teacher. However, if evidence is withheld and/or arguments are absent, then pupils cannot make a judgment about truth independently of their teacher; indeed such teaching leaves pupils intellectually dependent upon what the teacher says about the claim's truth.

Clearly, then, teaching which provides for Intellectual Independence introduces pupils to the intellectual undergirding of knowledge claims, in a way that is not available from teaching characterized as providing for Intellectual Dependence. The latter type of teaching leaves pupils quite unable to distinguish between valid and invalid

claims about the world, let alone quite unable to comprehend criteria used in establishing validity. So, these pupils can become intellectually tied to prevailing beliefs or to the beliefs of individuals without being in a position to make rational and informed judgments about these beliefs.

Not only can Intellectual Independence refer to potential outcomes of ways in which knowledge claims are presented, but also the construct can apply to more embracing propositions or assumptions, such as views of science and views of the world. For instance, science teaching might portray the world as totally describable in scientific terms, as was shown in Chapter IV. But, unless pupils are presented with the message that this is _one_ way of viewing the world, and unless the teaching shows the benefits and foundations of several ways of viewing the world, pupils cannot _judge_ rationally between such views. So, this teaching would provide for Intellectual Dependence--it leaves pupils dependent upon their teacher for particular beliefs.

Different Treatments of Pupils' Statements

Of course, statements about the world can be made by pupils as well as teachers in science lessons. And, the ways in which such statements are treated by a teacher can have significant consequences for pupils. For instance, in order that a pupil see for himself why his offering is valid or invalid, the teacher must ensure that the criteria by which the statement is judged are evident in the discourse. If reasons for accepting or rejecting a pupil's statements are not explicit,

then again, the pupil is intellectually dependent upon the teacher for judging the validity of the offering. But if reasons are given, then the pupil can judge the validity of his statement for himself.

Summary

Both the above aspects of teaching, then, can have considerable impact on the manner in which pupils come to decide upon the validity of knowledge claims of one sort or another. Basically, claims can be judged independently of another person's authority, or claims can be accepted on the basis of another's authority. The difference is significant. In short, Intellectual Independence speaks to the ability to make rational judgments independently of others, while Intellectual Dependence connotes a need to rely upon the authority of others for decisions of this sort.

Uses of "Teaching" and "Learning"

It is evident in the previous section that features of teaching which provide for Intellectual Independence or Dependence are related to one of Scheffler's epistemological views. And, it will be shown later that the terms are related to different meanings of the word "teaching," as well. Before these areas can be investigated (for the purpose of deriving the second category of the analytical scheme), it is necessary to distinguish between senses in which the term "teaching" has been used. Since this depends upon meanings of "learn," these must be discussed too. First, Komisar's analysis of the senses of "learn" is presented. Then, Scheffler's use of "teaching" is examined in relation to Komisar's "meaningful learning." Although Scheffler's meaning of "teaching" is narrow and specific, it will be used later in this chapter in relation to

teaching which provides for Intellectual Independence.

Komisar's Senses of "Learn"

Komisar finds that the senses of "learning" depend both on the content ("learning to play golf") and on the modes of learning ("learning the rules of golf" or "learning to play golf"). Four senses of "learning" are distinguished in this manner:

1. Meaningful: "learn that..."
2. Veridical: "learn the..." (also, how to, when to, and where to)
3. Active: "learn to..."
4. Committal: "learn to be..."[1]

Since the study is concerned with the intellectual consequences of what is said, and therefore with the knowledge claims made about the world and about science in lessons, only the meaningful sense of learning is central to this study. Thus it is not of current interest if the learning is veridical (for example, learning the three times table), active (as in learning to perform the action of typing), or committal (as in learning to be punctual), whereas it is of interest to examine meaningful learning for, as seen in Komisar's classification, this sense of learning is "learning that . . .," which is concerned with propositions. The present task is to examine "learning that . . ." to clarify conditions that must be satisfied, if provision to learn that is to become

[1] B. Paul Komisar, "More on the Concept of Learning," in Psychological Concepts in Education, ed. by B. Paul Komisar and C. J. B. Macmillan (Chicago: Rand McNally, 1967), p. 219.

provision to know <u>that</u> or to believe <u>that</u>. (It is taken that the belief in "believe that . . ." is quite distinct from what is implied by the committal sense of learning. For instance, if a person has learned to be punctual and is seen as always punctual, then there is no reason to suppose that his punctuality is a consequence of his <u>believing</u> that to be punctual is worthwhile or good. The committal sense of "learning" speaks clearly of an action, whereas the sense of "believe that . . ." intended here is one of accepting the truth of a proposition. Although it is not denied that propositional beliefs may be evidenced in action, the point is simply that a committal to a particular action does not necessarily imply the acceptance of a propositional belief that might be associated with that action.)

<u>Scheffler's Account of "Teaching"</u>

The relationship between Intellectual Independence and having at hand evidence and argument in support of a knowledge claim is strongly suggestive of a relationship between certain senses or types of "teaching" and their potential outcomes, which might be belief or knowledge. A useful account of a possible relationship between the terms "know," "learn," and "believe" is provided by Scheffler. It will be seen, though, that this relationship leads to a stipulative definition of teaching which is too restrictive for this study. Later, this stipulation will be used to denote teaching which provides for Intellectual Independence.

Scheffler places "know," "learn," and "believe" in relation to each other as follows:

> We are thus led to contrast <u>learning that</u> and <u>knowing that</u> in the

> following way: To say that someone has come to know that Q, commits us generally to the substantive assertion represented by "Q." For example, if we say of a pupil that he has come to know that Cornwallis surrendered at Yorktown, we are ourselves committed to the substantive assertion, "Cornwallis surrendered at Yorktown." To say that someone has learned that Q, does not so commit us; we are, in general, limited only to the claim that he has come to believe that Q.[1]

Scheffler points out that this sense of learn, which he calls the "tutorial sense," is distinct from the "discovery sense" found to be intended in statements such as "Reporters, after extensive investigation, learned that secret negotiations had been in progress for three weeks before the agreement was announced publicly."[2] As it stands, then, Scheffler claims that "learning that . . ." commits the creditor to the truth of the assertion said to be known. (The pivotal term in this distinction, "truth," is examined in more detail later in this chapter.)

Next Scheffler argues that "teaching" appears to lead to knowledge in the strong sense of "know" which requires something more than having true belief--"true belief" he identifies as the weak sense of know; that is, a person may believe Q to be true when in fact Q is true unbeknown to the putative knower. The transition from the weak sense of know to the strong sense of know is a function of evidence provided in support of the proposition which is believed to be true. Here, however, Scheffler is restricting the use of the term "teaching" to denote a specific type of activity, namely, the activity which has as its intended

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[1]Israel Scheffler, Conditions of Knowledge, op. cit., p. 8.

[2]Ibid.

outcome the strong sense of "know." This stipulative definition of teaching is derived from noting the "success" and "intentional" uses of the term "teach." That is, a person who is teaching, Scheffler asserts, is not only engaged in an activity leading to some pay-off, he is also intending to achieve this particular pay-off. Thus, it is argued, the intention of teaching is to bring about learning and, if the teaching has been successful, what has been taught will be believed.

Scheffler finds this to be an indiscriminating definition of teaching for he observes that there are many ways of leading people to adopt beliefs, such as deception, insinuation, advertising, hypnosis, propagandizing, indoctrination and others from which he wishes to make "teaching" distinct. To effect this distinction, Scheffler stipulates that teaching has " . . . distinctive connotations of rational explanation and critical dialogue."[1] From this it follows that:

> The person engaged in teaching does not merely want to bring about belief, but to bring it about through the exercise of free rational judgment by the student. This is what distinguishes teaching from propaganda or debating, for example. In teaching, the teacher is revealing his reasons for the beliefs he wants to transmit and is thus, in effect, submitting his own judgment to the critical scrutiny and evaluation of the student; he is fully engaged in the dialogue by which he hopes to teach, and is thus risking his own beliefs, in lesser or greater degree, as he teaches.[2]

Here, and elsewhere,[3] Scheffler is proposing what Martin has subsequently

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[1]<u>Ibid</u>., p. 10.

[2]<u>Ibid</u>., pp. 11-12.

[3]Israel Scheffler, "Philosophical Models of Teaching," <u>Harvard Educational Review</u>, XXXV (Spring, 1965), pp. 131-43. The section titled "The Rule Model" contains amplification of Scheffler's view of the concept "teaching."

called the "Rationality Theory" of teaching,[1] being designated here as "Teaching (R)" for immediate purposes.

It has been asserted above that Scheffler's definition of teaching--Teaching (R)--is stipulative, for only certain specific kinds of dialogue between teacher and pupil are allowed to be labelled as such. Two problems would be incurred if this stipulation were to be adopted for this study. First, stipulations are judgmental and this stipulation of what is to count as teaching carries an overtone of disapprobation toward classroom dialogues that are not Teaching (R), for Scheffler contrasts Teaching (R) with insinuating, indoctrinating and other activities that are likely thought as undesirable. The adoption of Scheffler's Teaching (R), then, might appear detrimental to the purpose of this study which is to describe classroom dialogues in terms of their potential consequences without passing judgment upon the appropriateness of the consequences and thus upon the desirability of the dialogues themselves. Second, if only certain stipulated types of dialogue are to be called "teaching," as Scheffler would have it apparently, then it is necessary to find a word to describe other types of dialogue that might commonly be called "teaching," such as that process by which youngsters come to learn their multiplication tables by rote, say. On the other hand, it seems undesirable to limit the study to an examination of the consequences of instances of Teaching (R) alone, for this might require

[1]Jane Roland Martin, Explaining, Understanding, and Teaching (Toronto: McGraw-Hill, 1970). The "Rationality Theory" of teaching is discussed within the context of explaining something to someone, as distinct from explanation per se, on pp. 89-103.

deletion of considerable data otherwise described as "science teaching."

For reasons mentioned above, the term "teaching" is used in this study to refer to any classroom discourse of a substantive nature which has potential for meaningful learning. The usefulness of Scheffler's account lies in his distinction between teaching that provides for knowledge and teaching that provides for belief. The epistemological differences that Scheffler notes here make stronger the case for examining epistemology as a possible source of discriminating items for use in the analytical scheme. Such an examination is the object of the following section.

The Traditional Three Conditions of Knowledge

In the previous section, there is an evident relationship between terms having epistemological connotations ("knowledge" and "belief") and different meanings of "teaching." To this investigator, this relationship is compelling reason to pursue epistemology as a possible framework by which different types of teaching might be identified. Accordingly, Scheffler's account of the traditional three conditions of knowledge is examined in this section.[1] It is apparent, however, that the conditions of evidence and truth pose problems of a sort which suggest that a purely epistemological framework is inadequate for the purposes of this study. The problems revealed below are discussed in the next section, and the constructs Intellectual Independence and Intellectual Dependence are introduced as a useful way of overcoming these

[1] Israel Scheffler, Conditions of Knowledge, op. cit.

problems within the context of this study.

Scheffler introduces his account with the claim that X knows (the proposition) Q if and only if: (i) X believes that Q, (ii) X has adequate evidence that Q, and (iii) Q (that is, the proposition Q is true).[1] These three conditions are discussed in the order in which they are presented by Scheffler.

Truth

Scheffler argues that the commitment to the truth of Q is objective, and is independent of the putative knower for, if it is true that X knows that Q, then it is also true that Q. Thus, knowing is incompatible with being wrong or with being mistaken. This version of the entailment thesis, that the statement "X knows that Q" entails the truth of Q, serves to separate knowledge from belief, so that it is possible to argue that the statement "X believes that Q" does not entail the truth of Q. Thus, whenever Q is asserted and Q is false, it can be said that the assertion is a reflection of a state of mind that is belief and not knowledge. Beliefs may be held despite considerable refuting evidence being at hand and this is not a property of knowledge. This result appears unexceptionable, but raises the problem of speaking about knowledge as if it were a state of mind--a problem revealed by Austin when he denied that the assertion "I know" indicates that a "specially striking feat of cognition" had been performed.[2]

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[1] Ibid., p. 17.

[2] J. L. Austin, "Other Minds," in Philosophical Papers, ed. by J. O. Umson and G. J. Warnock. (Oxford: Clarendon Press, 1961), p. 67.

Alternatively, it is not clear that "knowing" is an activity--it is unusual to speak of "I am knowing" as an activity similar to what is signalled by "I am typing." In resolving this puzzle, Scheffler remarks that it is typical to challenge a person's knowledge claim, but unusual to challenge the fact that a person believes a claim. Scheffler summarizes this as follows:

> The conclusion seems to be that knowing, unlike believing, has independent factual reference. The truth condition, which makes explicit this factual reference, thus seems to rule out the traditional (and still current) notion that knowing is simply and purely a cognitive task, faculty, activity, state, process, or performance.[1]

Next, Ryle's argument that knowing is an achievement and not a mental performance of some kind is invoked. The advantage of this distinction appears in recognizing that an achievement cannot fail--one cannot achieve something and at the same time not have achieved it. Scheffler claims that the inherent danger in this point is that knowledge might be thought immune from error--one either achieves or one doesn't, so one either knows or one doesn't--which is itself erroneous for it fails to acknowledge that weakness may be inherent in a particular procedure for achieving knowledge. For Scheffler, the distinction between tasks and achievements undermines, therefore, the notion that knowing implies not only truth but certainty. He summarizes:

> The notion of an infallible performance has here been gotten from the truth condition _plus_ the construal of knowing as a mental performance. The trouble is, as Ryle argues, that knowing is not a performance at all, and so cannot be an infallible performance.[2]

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[1] _Ibid._, p. 26.

[2] _Ibid._, p. 30. Scheffler uses arguments from the first chapter of Gilbert Ryle's _The Concept of Mind_ (London: Hutchinson House, 1949).

Knowing is thus an achievement in the same sense as a medicinal cure is, but the fact that there are cures does not imply that all curing processes are successful.

The distinction Scheffler has raised between truth and certainty leads him to question the possibility that there ever could be certainty. This he does in two steps. First, he argues that Hume's attack on certainty is "widely accepted."[1] Hume's attack, it is reported, is mounted upon the distinction between knowledge by pure thought and empirical knowledge. In the first, knowledge by pure thought is certain because the propositions of pure thought, such as those of mathematics, are discoverable by thought alone. In Ayer's terminology, this constitutes a system of circular truths derived from a priori assumptions about abstract number systems and the like.[2] The certainty of empirical knowledge, for Hume, is not attained by pure thought since no arguments can be constructed to absolutely justify causal generalizations and inductions. (There is no certainty that the sun will rise tomorrow despite the impressive number of cases that serve to support this generalization by induction.) Next Scheffler repudiates the phenomenalist thesis

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[1] Ibid., pp. 33-37. The portions of Hume's ideas used by Scheffler are from An Enquiry Concerning Human Understanding, Section IV (Parts I and II) and Section V (Part I). These portions of Hume's work can be found in Enquiries Concerning the Human Understanding and Concerning the Principles of Morals, ed. by L. A. Selby-Biggs. (Oxford: Clarendon Press, 1902).

[2] A. J. Ayer, Language, Truth and Logic (New York: Dover Publications, 1952), Chapter i.

that phenomenal facts are immune from error. Such statements as "It seems to me as if I were seeing a watch" are, he claims, at best offering, ". . . only a weak and transient type of certainty . . ." based as it is on memory of past experiences and a type of generalization about a class, the total membership of which might not have been seen. So:

> We have, in sum, very good grounds for rejecting the notion that knowledge always entails certainty, either in the sense of an infallible method of inquiry or in the sense of an incorrigible form of judgment.[1]

Scheffler considers the rise of pragmatism to be an attempt to answer the question of whether dropping the notion of certainty automatically forfeits the concept of absolute truth. In turn, he considers the pragmatism of Peirce and James. Of Peirce's view it can be said that particular ideas are clarified by whole statements in such a way that the meaning of a statement, such as "This stone is hard," is defined as a series of habits of action taken with respect to the stone and its supposed hardness. If such a series of statements were collected and it was agreed that the erroneous ones had been eliminated, it would appear that the remainder lead to an ideal, absolute truth in terms of a number of suppositions about the world. But nothing excludes the possibility that some erroneous statements would not be eliminated. According to Peirce, these would be revised in time, yet we cannot be sure they will. "Peirce's argument is that we cannot be sure that such an opinion will not be revised, but equally, he cannot be sure that it will, and indeed it seems to fly in the face of all probability to assume

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[1]Scheffler, Conditions of Knowledge, op. cit., p. 39.

that it will in every case."[1]

James' notion of truth is couched in terms readily recognized as belonging to the Instrumentalist view described previously, truth being accorded to any idea that usefully links ideas satisfactorily from one part of our experiences to any other part. But, as Scheffler notes, this instrumentalism raises the issue of what counts as "satisfactory." This, however, is not the sole problem with pragmatism as Scheffler sees it. He suggests that there is a fundamental confusion in these positions between absolute truth and certainty. Clearly, the issue of whether or not truth is an absolute property of statements is quite distinct from the problem of determining if we can ever be certain that we have arrived at that truth. Here Scheffler declares himself by arguing for the possibility of denying the notion of ever being certain, but upholding the notion of absolute truth. He illustrates this contention from science and demonstrates how former theories, though thought to be true, are now judged to be false. Thus, he argues, although opinion as to what is true is mutable, truth itself is not.

Two points might be added here. First, this view of scientific history appears consistent with the Realist view previously defined, and thus Scheffler's argument about truth and certainty may only be valid for the Realist position. Second, his argument appears weak, for there is no reason to suppose that what we now opine as true is supportive of the notion of absolute truth. In sum, the notion of absolute truth is

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[1] Ibid., p. 44.

probably of little use until such time as certainty is achieved, at which time absolute truth will be attained. Even so, as Scheffler has argued, there are good grounds for rejecting the entailment of certainty and knowledge. Therefore, whether "truth" in the truth condition refers to absoluteness or certainty seems to be a question transgressing the bounds of fruitful inquiry for this study.

The following points can be made to summarize this discussion of the truth condition. First, there is a problem as to what precisely constitutes truth. Indeed, the criteria for truth appear to depend upon philosophical position, and thus one could expect truth to have different criteria for Realism and Instrumentalism. As a result, it would be difficult to judge a portion of teaching on the basis of the truth of what is asserted.. (This would require one to commit oneself to a particular position about truth.) It therefore seems more appropriate to examine teaching for the presence or absence of means for assessing truth. It will be seen later that this approach can be used to overcome the problem of what precisely constitutes truth. So, instead of analyzing teaching for the truth of what is said, one can analyze teaching to see if means for determining truth are made evident to pupils, so that they can assess the truth of statements for themselves.

Evidence

Scheffler's arguments concerning the evidence condition are based upon a notion of evidence as a means for distinguishing knowledge

(formerly, his "strong sense of knowing that . . . ") from mere true belief, the latter referring to statements uttered out of ignorance which happen to be true. This, as Scheffler acknowledges, omits mention of guidelines for deciding upon what constitutes an adequacy of evidence. Adequacy, he finds, has an implicit reference to standards which vary and thus lead ultimately to numerous interpretations of knowing. Also, there are instances of knowledge for which evidence seems logically inapplicable. Thus Scheffler believes that one does not ask evidence of a person professing to be in pain, neither would one ask for evidence in support of statements having a high prima facie credibility, although in cases of this last type evidence is not logically inappropriate and might well be supplied.

Scheffler revises the evidence condition to reflect the notion of the "right to be sure," meaning having at one's disposal means for supporting claims. However, he allows that both the evidence condition and the right to be sure are weak in that they permit an allowance upon authority. And since merely having evidence says nothing of the need to arrange it into an appropriate pattern of proof, Scheffler adds to this condition the rider that the putative knower must be capable of this arrangement. This, in turn, demands a facility with, or understanding of, the language.

> When we judge that someone has adequate evidence, we are judging that he has an evidential argument which he understands. In saying he knows, we are not merely ascribing true belief but asserting that he has the proper credentials for that belief, the <u>force</u> of which he

himself appreciates.[1]

Here, although what constitutes evidence is still a problem, no teaching can make provision for knowledge unless it contains evidence and the argument into which the evidence can be seen to fit. The presence or absence of evidence and/or argument appear to be useful for distinguishing between different types of teaching on the basis of their potential consequences: belief or knowledge.

Belief

It has been shown that teaching might be distinguished accordint to whether it provides for knowledge or belief. From Scheffler's account, teaching provides for knowledge if it contains evidence, argument, and some attention to means of assessing truth. A lack of one of these conditions suggests that teaching is merely providing for belief.

Scheffler's discussion of belief is included here for two reasons: first, it completes the account of the three conditions of knowledge; and second, it points up the importance of distinguishing between belief and knowledge.

In addition to the previously mentioned argument that the presence of evidence transforms the status of belief to that of knowledge, Scheffler advances two accounts of belief, the verbal theory and the general dispositional theory. According to the verbal theory, belief is thought to be a disposition ". . . to offer an affirmative response

[1] Ibid., p. 74.

to certain sentences under appropriate conditions."[1] The problem with this theory inheres in its inability to cope with situations in which additional constraints are placed upon the respondent. (Scheffler uses an example featuring a spy undergoing torture in enemy territory.) Neither can this account be repaired by specifying that the respondent must respond according to his true belief, because this requirement is patently circular.

The general dispositional theory allows that a belief may be manifested in a number of ways additional to purely verbal responses, such as going to church and praying which are normally taken as manifestations of Christian beliefs. Yet a similar problem arises with this account when it attempts to deal with the actions and responses of persons under constraints. So Scheffler suggests that belief is rather a theoretical state somehow describing a person's orientation in the world.

Clearly, then, what is said in teaching can influence a pupil's orientation in the world. Furthermore, there is a significant difference between an orientation that derives from knowledge, and one that is derived from accepting the beliefs of others.

Summary

This discussion of Scheffler's account of the conditions of knowledge suggests that one can distinguish between outcomes of knowledge and belief as provisions of teaching. (One could look for the

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[1] Ibid., p. 77.

presence of argument, evidence, and discussions of truth in teaching to make this distinction.) But this epistemological framework is of limited use to this study, because of two problems: different criteria of truth, and lack of specific criteria for establishing the adequacy of evidence. These problems are addressed in the following section.

Intellectual Independence and Intellectual Dependence

It has been shown that a purely epistemological framework is of limited use for analyzing teaching since there appears to be no agreed upon means for determining absolute truth or the adequacy of evidence. Thus, it becomes difficult to characterize teaching as providing for belief or providing for knowledge. Since "believing" and "knowing" connote significantly different mental states (in terms of how one comes to accept a proposition as true), the investigator finds that distinguishing between types of teaching that provide for knowledge or belief is important. But, for teaching to be characterized in this way, the problems met in the truth and evidence conditions must be surmounted.

In what follows, arguments are provided to show how the problems can be overcome by broadening the intellectual consequences "knowledge" and "belief" to those denoted by the constructs "Intellectual Independence" and "Intellectual Dependence." It will be seen that these constructs have potential for characterizing teaching in a way preempted by problems with the truth and evidence condition. Briefly, rather than consider if a statement in teaching _is_ true, one considers the impact on pupils of providing or withholding means by which truth is assessed.

And, rather than puzzle over the adequacy of evidence available to pupils, one considers the impact on pupils of allowing them or denying them the chance to judge the adequacy of evidence for themselves.

The Problem with the Truth Condition

It has been seen that different criteria might be employed for determining truth, and that these criteria are related to philosophical views. (In particular, Realism and Instrumentalism have been shown to employ different criteria, and similar differences were noted between accounts of the Deductive and System Paradigms in Chapter III.) It is shown below that this problem with the truth condition cannot be resolved by pursuing the distinction between teaching which provides for knowledge and teaching which provides for belief. Instead, the broader construct "Intellectual Independence" and "Intellectual Dependence" must be employed.

A possible cause of the difficulty with the truth condition lies in the inappropriateness of applying a single criterion to all types of statements in attempts to assess their truth. In the previous chapter it was found that a different logical status is ascribed to "scientific objects" by the Instrumentalist and Realist positions, to the extent that "scientific objects" are thought of as either conceptual or real. This distinction has considerable bearing on the application of the truth condition, as can be demonstrated by temporarily adopting the Instrumentalist position and dividing statements into two types,

observational and theoretical.[1] Observational statements are those which report on states-of-affairs; their truth or falsity can be assessed by correspondence. Thus, the statement "There is a typewriter on my desk" is found to be true if a typewriter _is_ on my desk. According to the Instrumentalist position, observational statements will contain no terms referring to "scientific objects." Statements containing such terms are theoretical statements. Their truth is necessarily determined differently because "scientific objects" are conceptual, and so a theoretical statement cannot be "seen" to correspond with what is observed. Instead, the truth of theoretical statements is determined pragmatically such that the statement "It is useful to think of matter as being composed of atoms" would be accorded truth if indeed it is found that the conceptual device "atom" _is_ useful for explaining phenomena associated with matter.

Within a Realist framework, as defined in this study, the distinction between observational and theoretical statements cannot have the same consequence because "scientific objects" are believed to exist and therefore to be observable in principle. Therefore, the truth of a theoretical statement is, in principle, to be assessed by correspondence. So, the truth condition as presented by Scheffler applies differently to theoretical statements as seen from the two positions Realism and Instrumentalism. Accordingly, the problem might be resolved for the analytical

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[1]Hume makes a similar distinction in passages cited earlier and used by Scheffler in the latter's discussion of truth. A similar strategy is employed by John Wilson in his _Language and the Pursuit of Truth_ (Oxford: Oxford University Press, 1967), pp. 58-65.

scheme by noting that the truth of certain statements made in classroom dialogues would have to be assessed according to the type of statement and the position seemingly espoused in the teaching, Instrumentalism or Realism.

Despite its attractiveness, this solution has a severe limitation for analyzing teaching. It requires one to make judgments about truth which can be done only if one adopts one or the other view of science. In short, one is committed to judging the truth of what is said in the teaching, rather than analyzing the potential consequences of what is said.

A more useful approach to analysis would be one referring to the way in which a pupil's capacity for knowledge and judgment is treated in class. If one used this approach, it would be possible to identify instances of teaching in which pupils are permitted to exercise this capacity, or instances in which this use is precluded by what is said.

The concept "Intellectual Independence" is employed to denote the fullest exercise of this capacity for knowing. Here, a person who is intellectually independent in a particular field of knowledge is considered to be cognizant of the assumptions upon which judgments of truth are made. He will also be capable of judging the validity of claims made in this area on the basis of their supporting argument and evidence. Thus, makirg provision for Intellectual Independence is a more extensive intellectual consequence than is making provision to know. It is not enough that evidence be presented, and that what is claimed as true actually be true. For, without a pupil "seeing" how the claim is

found to be true, he will remain intellectually dependent upon his teacher (or his text) for its truth. The alternative to Intellectual Independence is thus Intellectual Dependence. This latter concept can be seen also as more embracing than making provision for belief. Belief, as noted earlier, involves the adoption of unsubstantiated assertions so that they are only believed to be true. If teaching is seen to make provision for belief by the absence of evidence and argument, then provision is being made for pupils to rely upon the intellect of others (for the truth of the assertion), and the exercise of Intellectual Independence is neither permitted nor fostered. In short, such teaching can be characterized as providing for Intellectual Dependence.

The "Adequacy of Evidence" Problem Surmounted

According to the above definition of Intellectual Independence, a person judging the truth of a claim must also be making some judgment about the adequacy of evidence supporting that claim. Teaching which allows pupils to assess the adequacy of evidence is providing for Intellectual Independence, while teaching that denies pupils this judgment is providing for Intellectual Dependence. It seems clear, then, that the constructs Intellectual Independence and Intellectual Dependence enable one to overcome the problem in the evidence condition as well as that in the truth condition.

Summary

The intellectual consequences described by Intellectual Independence and Intellectual Dependence have been introduced as broader and

more useful to this study than the notions of knowledge and belief. Teaching which makes evidence, argument, and means for assessing truth available to pupils provides for Intellectual Independence. If any of these features is absent, then the teaching provides for Intellectual Dependence.

The broad nature of Intellectual Independence and Intellectual Dependence can be seen when one considers activities in teaching somewhat different from the making of claims about the world. For instance, if pupils are to be able to judge the appropriateness of models or diagrams that are used in teaching, then evidence and argument must be available to show that these do correspond to what they are meant to represent. If these conditions are met, pupils can exercise Intellectual Independence. Furthermore, since Intellectual Independence speaks of a capacity for making rational judgments, then alternatives must be available for pupils to judge between. So, teaching that provides for Intellectual Independence would be characterized by the presence of alternative theories, say. But if alternatives are absent, then judgments of this sort are preempted. Such teaching would provide for Intellectual Dependence.

Later, these features will be collected to form part of the second category of the analytical scheme. Before this is done, two areas must be examined. First, Intellectual Independence and Intellectual Dependence are shown to be related to features of teaching which have emerged from the philosophical analysis of the concept. Second, it is shown that Intellectual Independence and Intellectual Dependence have added usefulness for analyzing teaching since they enable one to

characterize teaching according to the manner in which pupil's statements are treated in lessons. (The significance of this aspect of teaching was demonstrated earlier in this chapter.) These tasks are accomplished in the following two sections, respectively.

Analyses of the Concept "Teaching"

The purpose of this section is to show that the constructs Intellectual Independence and Intellectual Dependence are not isolated concepts. Not only are they related to epistemological features of teaching as shown in the previous section, they also have analytical connections with features of teaching and their consequences which have been derived from various analyses of the concept "teaching." These relationships are revealed below. First, points made by Scheffler and Oakeshott are presented to show how teaching which provides for Intellectual Independence is generally related to the concept "teaching." Next, Komisar's analysis is described to show fuller correspondence. Finally, teaching which provides for Intellectual Dependence is shown to correspond with the concept of indoctrination.

"Teaching" and Intellectual Independence

Scheffler's model of teaching has been discussed, and was designated "Teaching (R)" in an early section of this chapter. The emphasis of this way of construing teaching is upon providing for knowledge through exercise of rational judgment. Scheffler expands on this interpretation in the final chapter of Conditions of Knowledge and in his

paper, "Philosophical Models of Teaching." In the former he contends that rationality is a more extensive concept than intellect, encompassing both intellect and features of "knowing how" having to do with the appropriate exercise of skills.[1] Nevertheless, it is clear that Scheffler associates teaching with the use of intellect:

> Teaching may be characterized as an activity aimed at the achievement of learning, and practiced in such manner as to respect the student's intellectual integrity and capacity for independent judgment. Such a characterization is important for at least two reasons: first, it brings out the intentional nature of teaching, the fact that teaching is a distinctive goal-oriented activity, rather than a distinctively patterned sequence of behavioral steps executed by the teacher. Secondly, it differentiates the activity of teaching from such other activities as propaganda, conditioning, suggestion, and indoctrination, which are aimed at modifying the person but strive at all costs to avoid a genuine engagement of his judgment on underlying issues.[2]

Of immediate relevance is this delineation of what might be involved in Intellectual Independence, namely an engagement of judgment on underlying issues. It is clear that Scheffler's view of teaching corresponds to the type of teaching that provides for Intellectual Independence. Later, he seems to expand upon what he means by "intellectual integrity" by arguing that a putative knower must earn the right to a confidence in his beliefs by building an appropriate case for them based upon rational use of principles. It is alleged that the autonomy of the knower is evidenced by his ability to do this, and hence teaching should make provision for the recognition of this potential autonomy and the exercising of it. Although Scheffler's view of teaching has been seen to be

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[1] Op. cit.

[2] Scheffler, "Philosophical Models of Teaching," op. cit., p. 131.

somewhat perscriptive, it is clear that the outcome he has in mind for Teaching (R) is quite similar to Intellectual Independence.

Oakeshott makes a case for teaching that results in some means for handling imparted information, noting the responsibility of a teacher for imparting information and at the same time for providing pupils with a means for ". . . perceiving that it is something to be used" --a process he calls "judgment." Judgment, he finds, cannot be imparted like information, neither can it be learned and forgotten as can information: instead, it may be considered as an acquired ability to use information.

> "Judgment," then, is that which, when united with information, generates knowledge or "ability" to do, to make, or to understand and explain. It is being able to think--not to think in no manner in particular, but to think with an appreciation of the considerations which belong to different modes of thought. This, of course, is something which must be learned; it does not belong to the pupil by the light of nature, and it is as much a part of our civilized inheritance as the information which is its counterpart. But since learning to think is not acquiring additional information it cannot be pursued in the same way as we add to our stock of information.[1]

The significance of this analysis of "teaching" lies in the parallel between features of Intellectual Independence and Oakeshott's "judgment." There is, for instance, a similarity between being aware of the assumptions underlying claims (in Intellectual Independence) and having appreciation of considerations belonging to different modes of thought, both being quite distinct from the assimilation of bare assertions or information.

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[1]Michael Oakeshott, "Learning and Teaching," in The Concept of Education, ed. by R. S. Peters (London: Routledge and Kegan Paul, 1967,) p. 173.

Komisar's Analysis of Teaching

A detailed analysis of the concept "teaching" which demonstrates its intimate connection with intellectual outcomes and processes is provided by Komisar. He distinguishes three separate levels of usage for the term "teaching." First, "teaching" may refer to an occupation or type of work. Second, "teaching" may refer to a general enterprise engaged in by teachers in classrooms. Third, "Teaching characterizes an act or alludes to an act as being of a certain sort (belonging to a certain enterprise of teaching)."[1] Teaching as enterprise, it is alleged, includes all "cousined" activities such as indoctrinating, training, propagandizing, preaching, haranguing, and others; and, since all these activities are engaged in to produce changes which are accurately termed "learnings" then at the enterprise level it is hard to distinguish teaching from its cousined activities. Komisar notes that the "future referring" criterion is often invoked to effect this distinction, so that an activity may be considered as teaching

> . . . if the enterprise ends in not only learning, but learning that becomes suffused with reason . . .. The future reference can be disguised by stating the criterion as a special quality of the present intention. But saying that a teacher's intent to produce learning is unselfish and citing future reason in the learner's mind as attesting to the genuineness of the altruism all comes down to giving a future-referring criterion.[2]

For Komisar, there are two difficulties with this criterion: first, it

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[1] B. Paul Komisar, "Teaching: Act and Enterprise," in Concepts of Teaching: Philosophical Essays, ed. by C. J. B. Macmillan and Thomas W. Nelson (Chicago: Rand McNally, 1968), p. 68.

[2] Ibid., p. 73.

cannot be used to determine if teaching is happening at any particular instant; and second, if a pupil acheived the desired rationality it follows that whatever occurred in the classroom is to be labelled "teaching." In summarizing the first portion of his argument, Komisar states:

> Discounting occupational talk, teaching does not imply learning. This is the standard thesis and it is impeccable. But this is true only at the enterprise level where the concept of teaching is least distinctive. The situation, I will go on to contend, reverses at the act level: here "teaching" finds its most exclusive and precise meaning and, what is more surprising, here also use of the word can imply the achievement of teaching's endemic goal, albeit that goal is not learning.[1]

At the act level, Komisar argues, teaching may be distinguished from its cousined activities by the presence of intellectual acts such as proving, demonstrating, elaborating, explaining, instancing, comparing, and others, the intent of which is not learning, for learning implies a disposition and thus is not fulfilled unless there is some lasting effect on the pupil. Instead, the intent of an intellectual act which, for Komisar, distinguishes teaching acts from other acts, is a form of awareness on the part of the auditor to whom the act is directed. Thus, if there is a problem to be solved, the teacher's intent is to have pupils ". . . figure out the solution, not 'learn the figuring out'."[2] The intellectual act thus implies the concurrent achievement of the goal. In effect, Komisar is claiming that one cannot be engaged in the act of instancing something for someone, say, unless that someone is instantaneously aware of the occurrence of the act of instancing. This does not

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[1] Ibid., p. 74.

[2] Ibid., p. 78.

deny the possibility of instancing things for oneself, thereby making it odd to state "I am instancing these events on paper." The claim is that if an act is justifiably to be called a teaching act, then an auditor must be aware of the act at the time it is occurring.

A second distinguishing feature of intellectual acts is that for them to be considered as teaching acts they are to be "logically lucid." By this, Komisar means not only that the performance must be accompanied by an awareness on the part of the auditor, but also that the act must be prefaced so that its intention is made plain and reasons are given to justify making the auditor aware of the performance. It can be seen that this feature distinguishes teaching acts from "cousined activities" for activities such as deceiving, indoctrinating, etc. make no pretense at being logically lucid. For example, it would be pointless and contradictory to its intent to preface an act of deception with a statement such as "I am going to deceive you in the following."

In making "teaching" more distinctive, Komisar has selected acts which are intellectual and appear to have consequences similar to those of Teaching (R). Thus the similarity between Komisar's teaching acts and teaching (in the sense used in this study) that provides for Intellectual Independence is established.

"Indoctrination" and Intellectual Independence

In the following it is shown that there is a clear conceptual link between Intellectual Dependence and the potential outcome of indoctrination: the intended outcome of indoctrination is necessarily

Intellectual Dependence. But this does not imply that all teaching which provides for Intellectual Dependence is indoctrination. Indoctrination is said to be intentional, and it is possible that a teacher provides for Intellectual Dependence without intending to do so. This action would not qualify as indoctrination.

Much of the analysis of "indoctrination" has been concerned with the teaching of morals and religion in schools. Flew has suggested that indoctrination may be considered as having a primary and secondary sense. In the primary sense, "indoctrination" describes the implanting of doctrines which are false or not known to be true, and in the secondary sense "indoctrination" applies to the implanting of doctrines by disapproved methods.[1] The primary sense, then, has an impact similar to providing for Intellectual Dependence, for a teacher cannot intend to propagate falsities, and at the same time provide a comprehensive means for determining their truth.

Similarly, Flew's secondary sense of indoctrination suggests that its outcome is intended to be Intellectual Dependence. If the intent is to implant doctrines, then it might be necessary to withhold evidence and argument, especially if pupils are critical of the doctrines. But there is a difficulty with Flew's secondary sense for it contains the criterion of disapproved methods. One might approve the withholding of evidence and argument in certain situations, and so <u>that</u> process might not qualify as indoctrination. All the same, the potential <u>consequence</u>

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[1]Anthony Flew, "What is Indoctrination?" <u>Studies in Philosophy and Education</u>, V (Spring, 1966), pp. 281-306.

of that process is still Intellectual Dependence.

Green provides an analysis which seems to place Intellectual Dependence as the potential consequence of indoctrination rather than Teaching(R), say. He addresses himself to the task of sorting and arranging along a continuum verbs within the family of "teaching verbs." This continuum extends from actions to beliefs and makes distinct indoctrinating and instructing. The latter, Green suggests, involves matters of truth and falsity, whereas indoctrinating ". . . aims simply at establishing certain beliefs so that they will be held quite apart from their truth, their explanation, or their foundation in evidence."[1] Patently, the potential outcome of indoctrination and teaching that provides for Intellectual Dependence are the same. Both leave the recipient of the act dependent upon the perpetrator for assessing the truth of statements transmitted during the act.

Crittenden attempts to discredit analyses of indoctrination and teaching that rely upon politically normative elements, such as democratic teaching, and/or prescriptive elements, such as Scheffler's model of teaching, Teaching (R). Two criteria are presented for recognizing indoctrination which is miseducative. First, a teacher presents content in a way that violates criteria of inquiry, presenting unwarranted claims, or suppressing critical evidence and reasons, for instance.

[1]Thomas F. Green, "A Topology of the Teaching Concept," in Philosophical Essays on Teaching, ed. by Bertram Bandman and Robert S. Guttchen (Philadelphia: J. B. Lippincott Company, 1969), p. 39.

Second, the teacher uses a method inconsistent with the requirements of inquiry and moral principles.[1] Aside from moral principles, if the requirements of inquiry are absent or violated, then the potential consequence is Intellectual Dependence. Again the link between Intellectual Dependence and indoctrination is made by concentrating on potential consequences without reference to the intent.

Despite the emphasis upon moral education in discussions of indoctrination, it has been noted by Nelson in a recent overview of papers written on the topic that indoctrination, as a concept, probably has relevance to the teaching of other disciplines because the analysis of the concept suggests a careful appraisal of the means by which beliefs are transmitted and thence adopted.[2]

Summary

These analyses all indicate that Intellectual Independence and Intellectual Dependence share features of various types of teaching that have been identified by the philosophical analysis of the concepts "teaching" and "indoctrination," respectively.

It has been seen that notions of judgment and knowledge (in Scheffler's strong sense) predominate in discussions of the concept "teaching" while the propagation of beliefs by methods that deny judgment

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[1]Brian Crittenden, "Teaching, Educating, and Indoctrinating," Educational Theory, XVIII (Summer, 1968), pp. 237-52.

[2]Thomas W. Nelson, "Analytical Philosophy of Moral Education" Philosophy of Education 1967: Proceedings of the Twenty-third Annual Meeting of the Philosophy of Education Society, ed. by D. B. Gowing (Edwardsville, Illinois: Philosophy of Education Society, 1967), pp. 250-58.

and encourage a non-critical acceptance appear to be associated with indoctrination. Consequently, the notions of Intellectual Independence and Intellectual Dependence have been shown to embrace the consequences of various types of teaching that have come under scrutiny in philosophical analysis. So, Intellectual Independence and Intellectual Dependence are not isolated concepts. They are related to specific epistemological positions and to products of the philosophical analysis of teaching.

It has been stated previously that these concepts are additionally useful in that they embrace features of teaching other than those related to epistemological features of the discourse. These distinctive features are discussed in the next section.

Distinctive Features of the Teaching Interaction

Arguments in this section reveal features of teaching whose potential consequences can be subsumed beneath the constructs "Intellectual Independence" and "Intellectual Dependence." These features have to do with features of teaching interaction which make it quite distinct from other forms of social interaction. It is shown that these features enable one to speak of the prerogatives of pupils in classrooms. From here, the argument establishes how different ways in which pupils' responses are treated can be related to pupils' prerogatives, and thus to Intellectual Independence of Intellectual Dependence.

Komisar has demonstrated that teaching is an inauthentic social

encounter.[1] He suggests that social encounters might be divided into three types: offerings, gifts, and services. As a social act, an offering is adequately describable on its own terms; that is, its description does not require a reference to the person to whom the offering is made. But gifts and services, it is argued, require for their completeness a participation by a second party. Gifts typically require a receiver before they can be described as gifts; services require a solicitation for them by a second party before they can be properly described as services. Not only are gifts characterized by their lack of solicitation but they are also not contrived. Komisar points out that teaching is an inauthentic human encounter because it is a service masquerading as a gift, for teaching is contrived and ". . . thrust upon minds not fit out to welcome, avoid or even appraise it."[2] This "thrusting," intrusive feature of teaching is claimed as necessary to the teaching act. One cannot teach without intruding upon a pupil's "mind-stuff."

> So the obvious is true, to teach and leave the learner unaffected is not to have been teaching at all. To reassure or prove something to a student is <u>to do something to him</u>. And one cannot prove the thing so the student can decide whether he wants it proved to him![3]

Clearly, for teaching to commence, the pupil must at least be temporarily denied any right or prerogative which might be invoked to nullify or offset the intrusion. This suggests that it might be fruitful to

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[1] B. Paul Komisar, "Is Teaching Phony?" Teachers College Record, LXX (February, 1969), pp. 407-11.

[2] Ibid., p. 410.

[3] Ibid., p. 409.

investigate the prerogatives that obtain in teaching situations.

Generally, verbal interactions are characterized by the intrusion of the speakers upon each others perceptions; yet the participants are usually at liberty to prevent further intrusion by requesting that the interaction cease. Another characteristic of general verbal interaction is that it carries with it no coercion for taking physical or intellectual action upon the request of a participant. So neither participant is especially empowered with prerogatives which would permit him to coerce the other into any form or course of action. The absence of any legal or logical permissions to coerce allows much freedom for legitimately declining to take action.

In some societal institutions there are instances of verbal interaction in which a participant may exercise certain prerogatives over another participant. For example, in courts of law there are complex hierarchies of prerogatives governing as admissible the interactions of judge, jury, defense, and prosecution--these prerogatives apparently intended for the proper administration of justice. Thus, upon taking the oath, a witness is compelled to answer truthfully, or suffer the penalties of perjury. This compulsion may be thought of as a manifestation of a contractual prerogative by which the witness has bound himself to the truthful answering of questions. The witness is protected against inadmissible questions by certain criteria overseen by the judge. Other examples of social interactions governed by predetermined prerogatives may be found in military services. An individual enrolled in such service has, as it were, entered a contractual prerogative obligating him to obey the orders of his superiors.

Such contractual prerogatives may be detected in classrooms, and these are quite distinct from the legal obligation upon pupils to attend and teachers to teach. A feature that distinguishes the prerogative of classrooms from those inhering in other societal institutions is the seemingly undisclosed nature of the classroom prerogative. In the classroom setting, a pupil may be thought of as entering a contract to have something done to him, but at the time when he enters the contract he logically cannot be aware of the full extent of what is to be done, for he has yet to submit to teaching. For this reason the nature of the contract entered by the pupil remains undisclosed and will probably remain so until the outcome of teaching is attained, at which time, of course, the contract can be thought to expire. Notably, whatever the (undisclosed) content of this contract, a teacher is legitimately exercising <u>his</u> prerogative by insisting that a pupil submit himself to teaching. Thus a teacher appears to be in a position to require intellectual (and perhaps physical) action of pupils while they appear to have no recourse to resist. Alone, this suggests a pupil has no prerogatives for counteracting the intrusion of teaching upon his perceptions, and <u>that</u> appears characteristic of all teaching.

If, however, teaching is seen to make provision for Intellectual Independence, then it is possible to establish that a pupil is being permitted to exercise prerogatives which partly offset the intrusiveness of teaching. Most basically, Intellectual Independence involves the capacity for making judgments about knowledge claims for oneself. It has been seen that provision of evidence in support of such claims and

"seeing" how their truth is determined are necessary conditions for making such judgments. Accordingly, when a pupil is provided with these conditions and permitted to judge claims for himself, his potential for Intellectual Independence is being honored. This, in turn, permits him to order his perceptions about the world in such a way that he is aware of what he is doing and why, as opposed to requiring him to order them in some prescribed fashion. And this allowance may be interpreted as giving a pupil the right to exercise a prerogative that is his alone, that of <u>choosing</u> how he will order his experiences--a responsibility that is ultimately his.

Thus pupils have prerogatives in the teaching discourse, and what bears upon the consequences of the discourse is the extent to which pupils are permitted to invoke these prerogatives. If provision is being made for Intellectual Independence, then these prerogatives can be used by pupils to offset the intrusiveness of teaching, to the extent that pupils are equipped with means to judge the teaching to which they submitted. Alternatively, teaching that provides for Intellectual Dependence does not permit judgment of the content taught, so it <u>does</u> prevent pupils from using their prerogatives.

So, respecting the personal prerogatives of pupils seems closely allied with providing for Intellectual Independence. Alternatively, if these prerogatives are not respected, then it seems that teaching provides for Intellectual Dependence. A survey of some ways in teaching by which these personal prerogatives might be respected suggests other features of classroom discourse which provide for Intellectual Independence.

If a pupil offers a response to a question then it would appear that he has the right or prerogative to have that response honored and treated with due regard to reason. A response rejected out of hand clearly violates this prerogative, for the teaching can be seen as failing to comply with other features of teaching which provide for Intellectual Independence, such as the provision of evidence or argument. Consequently, when a response or an unsolicited offering is not honored nor treated with regard to reason, that portion of teaching can be characterized as providing for Intellectual Dependence.

In summary, arguments in this section have demonstrated that concepts of Intellectual Independence and Intellectual Dependence have broader scope than might be available from characterizing teaching according to provisions such as knowledge or belief. Intellectual Independence and Intellectual Dependence also embrace potential consequences of ways in which teaching permits pupils to exercise certain prerogatives.

The Second Category of the Analytical Scheme

This chapter has offered support for investigating classroom discourse according to the provisions of Intellectual Independence or Intellectual Dependence. Features of these consequences were established as the concepts were developed from epistemological considerations, and from aspects of the philosophical analysis of teaching. These features are collected below as items of the second category of the analytical

scheme.[1]

Intellectual Independence

Teaching that provides for Intellectual Independence will have one or more of the following features:

a. Evidence is provided in support of claims.

b. The strategy of truth determination is evident.

c. The argument is present.

d. The correspondence of diagrams or models to phenomena is demonstrated by evidence and argument.

e. Reasons are given for the acceptability of a pupil's statement or response.

f. The questions and objections of pupils are honored and are treated with regard to reason.

g. Pupils have provision to make judgments of the viability of models and theories by recourse to phenomena.

h. Alternative models and theories are provided to permit pupils to make judgments among them.

Intellectual Dependence

Teaching that provides for Intellectual Dependence will have one

[1]The second category of the analytical scheme, found reproduced in the Appendix, p. A3, is headed "Category 2: Provision For Intellectual Independence Or Dependence." In tables that accompany the statistical analysis in Chapter VI, this heading is abbreviated to "Category 2: Intellectual Independence/Intellectual Dependence," and individual items of the scheme are referred to in the lesson analyses appearing in the Appendix as II-a or ID-a, etc., according to the item being used and the part of this category to which it belongs.

or more of the following features:

a. Evidence is not provided in support of claims.

b. The strategy of truth determination is not evident.

c. The argument is absent.

d. The correspondence of diagrams or models to phenomena is not demonstrated by evidence nor by argument.

e. Reasons for the acceptability of a pupil's response are absent.

f. The questions and objections of pupils are not honored and are not treated with regard to reason.

g. Provision is not made for pupils to make judgments of the viability of models and theories by recourse to phenomena.

h. The making of judgments among alternative models and theories is preempted since alternatives are not provided.

Summary

The formulation of the second category of the analytical scheme brings the theoretical component of this study to a close. Chapters III and IV showed the development of the first category of the scheme from considerations in the philosophy of science. In this chapter, the second category of the scheme was derived from epistemological considerations and from aspects of the philosophical analysis of teaching.

Although a purely epistemological analysis of teaching appeared promising at the beginning of this chapter, difficulty with the traditional account of knowledge (particularly with the truth and evidence conditions) led to the derivation of the constructs "Intellectual Independence" and "Intellectual Dependence." Not only does this

conceptualization provide a means for resolving problems with the traditional account of knowledge, it also corresponds to various conceptions of teaching found in philosophical analysis. So the conceptualization is not isolated. Furthermore, an attempt to expand upon some notions of pupils' prerogatives in classrooms yielded additional features of the conceptualization. All these features became the items of the second category of the analytical scheme, above.

The remainder of the study is concerned with demonstrating that the analytical scheme can be used reliably to detect intellectual consequences provided by classroom discourse. This empirical component of the study is described fully in Chapter VI.

CHAPTER VI

THE EMPIRICAL COMPONENT OF THE STUDY

The purpose of this study, as stated in Chapter I, is twofold: first, to demonstrate the importance of certain selected intellectual consequences of science teaching, and second, to produce an analytical scheme for detecting reliably whether or not provision is made for these consequences in classroom discourse. The preceding chapters have established the significance of investigating two alternative views of science (Realism or Instrumentalism) provided in teaching, and of the provision for Intellectual Independence or Intellectual Dependence. Moreover, the analytical scheme has been derived from features of these two sorts of consequences.

This chapter completes the second purpose of the study. It demonstrates that the analytical scheme can be applied to lessons and that provisions for the above consequences <u>can</u> be detected reliably. Procedures used in establishing these claims are described fully in the five sections of this chapter.

First, the problem of ascertaining the context in which pupils might understand a lesson is recalled. Sample analyses in Chapters I and IV depended upon the assumption that statements are understood in an "ordinary language" context. Furthermore, it was noted in Chapter V that one needs to know if evidence and argument in support of claims have been presented in previous lessons. The first section of this chapter, then,

describes the interview procedures adopted to determine the context of lessons used in the empirical component. Data for the empirical component consist of a series of science lessons and interviews with teachers of these lessons. Procedures used for collecting these data are described in the second section. Here, special attention is given to the interview protocols to illustrate difficulties encountered in determining context.

The investigator used two of these lessons to see whether or not the theoretically derived items of the scheme could, in fact, be used to analyze classroom discourse. The third section describes how this was accomplished, and presents reasons for modifying the analytical scheme. It is this revised version of the scheme whose reliability is determined. The fourth section describes procedures by which the investigator could show that the scheme can be used reliably. This involved the use of three independent judges analyzing a lesson with the scheme. The statistical estimation of reliability is presented in the fifth section. Here, it is shown that the overall percentage of agreement among the independent judges is 82.3 per cent. The agreements obtained are estimated to be statistically significant at the .01 level of confidence.

Disagreements among judges constitute practical limitations of the scheme. These disagreements are examined in Chapter VII.

The Problem of Context

Analyzing a lesson without attending to the context in which the lesson might be understood by pupils can limit the validity of claims about provisions made in two ways. First, it could be that the meanings

of statements are not taken in an "ordinary language" context, as was assumed when analyzing the text excerpt in Chapter I and the portions of teaching in Chapter IV. So, the view of science provided for (as detected by the scheme) might be quite different from that in fact provided by statements whose context was established in a previous lesson. For example, the analyzed lesson might seem to provide for a Realist view of science. Yet, in a previous lesson, the teacher might well have explained that, although statements can be interpreted in an "ordinary language" context, they have a different meaning--perhaps coinciding with Instrumentalism.

Second, although the analytical scheme might suggest that a lesson provides for Intellectual Dependence because, say, no evidence is provided to support a knowledge claim, this characterization could be quite false if evidence was provided in a previous lesson. Here context is also important, then.

So, the use of both categories of the scheme for making valid claims about intellectual provisions depends substantially upon the context, which might not be evident from the lesson itself. Accordingly, for the investigator to claim that provisions of teaching can be detected by the scheme, the context of lessons has to be determined.

Of many possible procedures for finding context, the investigator decided to interview teachers following each recorded lesson.[1] This

[1]An alternative way to determine context would be to observe and record a whole sequence of science lessons with one class over an extended period of time, such as a term or a year.

method is consistent with the intent of the study. If pupils were interviewed or tested, then claims about provisions would rely upon the assumption that context given by pupils was in fact a consequence of previous teaching. But this study has attempted to avoid claims about the actual outcomes of teaching, so such questioning of pupils is inconsistent with the intent of the study. (Teachers were interviewed, rather than tested, because it seemed unlikely that similar questions would have to be asked for each lesson. Indeed, this was the case.)

The decision to detect context from interviews influenced the collection of data in three quite practical ways. First, it restricted the range of lessons that might have been recorded, for each interview had to be conducted immediately following each recorded lesson. So, teachers offering to contribute their lessons to the study could only contribute those which immediately preceded a free school period. Second, to ensure that interviews covered all necessary points about context, the investigator had to use an early version of the analytical scheme, and make notes during the teaching of what questions had to be asked. Finally, in some cases, the interviews proved difficult to conduct, either because the questions were necessarily intrusive, or because matters relating to the status of theories and scientific objects were not understood by some teachers. These points are discussed fully in the following section.

Collection and Presentation of Data

Lessons and interviews recorded for this study have been used in three ways: to revise items of the scheme, to provide material for

analysis by three independent judges in determining the reliability of the scheme, and to provide material for illustrating the use of the scheme in lesson analysis.[1] Procedures used for collecting data, and the format of their presentation are detailed in this lengthy section, portions of the data being provided to exemplify points mentioned in the text.

Lessons

A total of fourteen science lessons were recorded for this study.[2] In all but one instance, the lessons were taught by different teachers. It was thought that obtaining two or more lessons from the same teacher might lead to difficulties since, after an interview, a teacher might alter his teaching in accordance with his perceptions of the interview and what was being sought in lessons. In the one instance a teacher had thought that two lessons were required of him, and these were both recorded since he had arranged his timetable to accommodate the investigator's visit on that day.

The lessons were all in the physical sciences at either the grade nine or ten level. Previous experience in analyzing science lessons led the investigator to believe that the relatively high percentage

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[1]Two transcribed lessons and their interviews appear in the Appendix of this document. The first of these lessons is that used in estimating the reliability of the scheme, and it is accompanied by the three separate analyses. The second lesson is analyzed by the investigator only, and is included to further illustrate the use of the scheme in lesson analysis.

[2]As reported later in this chapter (p. 181), only three of those lessons were used in the empirical component of this study.

of theoretical content in lessons at higher grades (possibly due to the college-preparatory intention of syllabuses) tends to obscure analysis. Consequently, it was thought that junior science lessons were more suited to this component of the study. As it happened, this decision did not restrict the variety of subject matter recorded, for many schools appeared to be teaching different syllabuses, and the recordings were spread out over a period of about one month. The variety of subject matter recorded is illustrated in the following list of topics selected from recorded lessons: refraction of light, reflection of light, particle theory of light, geometrical optics, current electricity, static electricity, simple chemical decomposition, simple molecular theory, conductivity of solutions, chemical changes, work and power, the voltaic cell. Further variety was available among these topics for teachers were found to be discussing different aspects of these topics, at different times.

The teachers recorded during this phase of the study were contacted via personal acquaintances in the school systems of southwestern Ontario. It was hoped that personal introductions would relieve teachers of some of the strain that might accompany having their teaching recorded and observed. At the time of introducing the study to teachers, it was felt detrimental to the study to describe the full purpose in detail. To disclose the sorts of things looked for in the analysis might well have influenced the manner in which teachers volunteering their lessons might have taught. All the same, it appeared unethical to describe the study falsely for the sole purpose of obtaining data that were objective as near as possible. Thus, the study was described as an

attempt to show that efforts at studying teaching, which relied upon what pupils learned, are misconceived, and that the study might be thought of as an attempt to attack the prevalent view that teaching implies learning. Teachers were informed that for this point to be made, it was necessary to collect data that could be used to indicate how teaching might be analyzed without resorting to measurements of what pupils learned. The need for interviews was explained on the basis of having to know something of the context in which lessons were given. It was emphasized that the analysis to be performed on recorded and transcribed lessons was not in any way judgmental, but was directed at finding clues in the teaching that would indicate what sorts of things pupils could be expected to learn from it.

Lessons were taped on a reel-on-reel tape recorder using a single microphone placed about one third down the side of each classroom and directed toward the class. This arrangement has proven successful in picking up statements of pupils--the investigator having found that the teacher's voice is sufficiently clear and loud to be detected by the microphone irrespective of its placement. During the lesson, the investigator monitored the recording level, noted material that would not be recorded (such as board writing, pupils' movement, and demonstrations), and attempted to follow the lesson and note items that seemed in need of some explication of context. Two lessons were recorded in this fashion, but it was found that the quality of accompanying interviews appeared to suffer as a result of the investigator's inability to handle all the necessary details as the recording was being made. Consequently, the remaining twelve lessons were recorded with the assistance of a

colleague who undertook responsibility for monitoring recording level and for noting non-audio matters. The investigator was then free to concentrate upon the lesson and think of the questions that would have to be asked during the following interview. This arrangement proved quite satisfactory.

Interviews

The sorts of questions that needed answering in the interviews were generated by applying an early version of the analytical scheme to the ongoing lesson. In this way the investigator was able to list constructs, theories, laws and conventions mentioned during the lesson and ask questions that would indicate how they were presented in previous lessons, what sort of support was invoked for them, what sorts of evidence were available, and such like. As indicated above, the conduct of the interview presented problems. First, it was necessary to place the teacher at ease as much as possible. This was attempted by casting the questions in a form that spoke of what pupils had done previously or of how certain items had been introduced. It was found that such questioning techniques required some skill and practice. Consequently, after the first two lessons and interviews, recording sessions were spaced further apart so that tapes might be transcribed and interviews scrutinized prior to further recordings.

Second, a major problem for the interviews resulted from questions based on the first category of the analytical scheme. Here, the intent was to determine the view of science provided for by the teaching, using the alternative positions, Instrumentalism and Realism.

Technically speaking, if a person has never deliberated the possibility that there are alternative views of science (based as these are upon questions of ontology and the nature of reality), then that person can be described as a naive realist. But to ask questions that cause this person to think about matters of ontology and reality is to have this person think about such matters and this, in effect, prevents the justified application of the definition "naive realist" to this person. Clearly, this technical aspect has considerable impact upon the sorts of questions that might be asked of teachers who apparently present a Realist view of science in their teaching, and the questions require careful wording to avoid influencing the interviewee.

These two difficulties are illustrated in the following examples extracted from interviews conducted during the study, and some indication of the interview procedure is provided as well.

Minimizing Threat to the Teacher.--Generally, it was found useful to preface the interview with introductory remarks to remind teachers of its purpose. Thus, the interview following the ninth lesson begins:

> Interviewer: I'd just like to repeat that the purpose of the interview now is to try and get information so that I can determine how the youngsters understand things, because you've obviously done a lot of work in statics and this sort of thing...
>
> Teacher: Yes, I did.
>
> Interviewer: ... and so they know something. What I need to find out is how they see that present lesson and how they understand it. So the questions tend to be quite pointed to get at the information. They're not evaluation questions then--they're in order to pull out the information. First of all, perhaps you could start by describing some of the work which you've done in static electricity.

Here an attempt is made to forewarn the teacher of the "pointedness" of

questions, and to emphasize that evaluation is not the intent of the interview. Possibly the preface to the interview following the fourteenth lesson is more successful in placing a teacher at ease, for no mention is made of the teacher--the subjects of sentences are the interviewer or the pupils. The extract is briefer as a result of talking with the teacher at some length prior to the lesson,

> Interviewer: The purpose of the interview is to try and get an understanding of the context in which the lesson is given. A lot of stuff has gone on beforehand and clearly the youngsters come here with an understanding of a number of things as evidenced by the answering of the questions. So, I have to ask a number of questions to get at certain pieces of information. For instance, is this the first time that they've looked at a chemical reaction this year?

General Questions about Context.--The questions following this type of introduction dealt with quite ordinary matters of what pupils might have seen or not seen, often in an attempt to determine the sorts of evidence that might have been presented previously. For example, in the fourteenth lesson, pupils are required to identify mercury and the context of this is pursued as follows:

> Interviewer: Um, what have they actually done in the experiment on mercury? It was clear from the lesson that they heated it, but how about their observations of mercury itself? Had they seen it before in order...

> Teacher: Of yes. We've...

> I: ...to be able to identify it.

> T: Yes. I would expect them to be able to do that very easily. Let's see, er...we've dealt with mercury in making thermometers. er...changes of state--not that they've actually used it, but they ...--they've seen the construction of a barometer, so they've dealt with mercury there. It's not a new substance to them.

> I: Right. How about oxygen?

> T: This is the first introduction of oxygen.

In the tenth lesson, pupils were shown a list or series on the chalk board, and it was necessary to know if they had seen how the series was derived from experiments. The context in which the series might be understood was determined as follows:

> Interviewer: We go now to the list you had on the board with "increasing ability to hold electrons" going down. Is that the first time they've seen that list?
>
> Teacher: Yes.
>
> I: Now. Do the materials that are listed there correspond to the materials that they have tested in the lab for themselves or that they've seen you work with?
>
> T: Yes. We have done wool, cat's fur, ebonite, er, and glass. We've done four of the materials.
>
> I: And had you compared them at all so that they can see the ordering coming out of the experimental work?
>
> T: No, I hadn't. Er, simply, I had...through the experiment with two types of rods, they, er, observed that they were different charges. And I said, "For the time being, ebonite is negative, glass is positive." And they just used this, and then this would be the only explanation I would give them as to why.

From this extract one can infer that pupils had little or no opportunity to see how the series they are to use in the lesson has been derived.

Questions Regarding View of Science.--The most awkward portions of interviews about context were those requiring that questions be asked about reality and ontology. In some instances, it seemed that the questions were not fully understood, and in these cases it was found useful to return to a similar type of question--often relying upon a different construct--in a later part of an interview. A number of rather lengthy examples are presented here, in order to illustrate the difficulties encountered in pursuing this particular aspect of context.

The first example is taken from the fourth interview. As can be

seen, there is a considerable amount of ambiguity in the teacher's responses, and the interviewer appears unable to grapple with it and achieve clarity:

> Interviewer: ...you talked just now of talking about charges and electron pairs. So, presumably they have some sort of understanding of the word "atom."
>
> Teacher: Yes.
>
> I: I'd like to ask you what sort of understanding you think they have of that.
>
> T: Er, rather on the...on the model level. Um, we've done a whole heap of experiments on electrostatics. They know something of the behavior of opposite charges and like charges. And then I represented the atom for them simply as a positively charged nucleus with something equally negative all, you know...equally in the opposite direction buzzing around the outside giving the whole thing a neutral charge and the fact that there are opposite charges holding the whole thing together as a unit. But then, under certain circumstances, given...given the right kind of combinations, the negativeness can be lost to other things, giving you a charged particle. I mean, just by rubbing the thing with wool for instance, you know, you can remove some of the negative charges and the thing becomes positive. They understand that idea.
>
> I: Um. sort of as a last, difficult question. Is an atom a real thing to them, do you think? (Pause)
>
> T: No, I don't think it honestly is, yet. Um, because right up till yester...right up to yesterday there were still a number of people, you know, who said, "Well, how do you know?" And if they...if they...if they're prepared to ask that question, it obviously means that they haven't any conception of the scale of that...of the atom. Um, there is an experiment that we do--we did last year which I didn't think was worthwhile doing this year because it's er, the mathematics is fairly complex--whereby we actually measure the dimensions of a molecule which, you know, in a way sounds a good thing. But their appreciation of...of what 10^{-6} or 10^{-7} is, you know, is not...is not good enough I think to make it worthwhile going through all the maths necessary to get that figure. So, er...they don't know how big an atom is, no. We've studied Brownian movement, they can see that they must be...they're so small as to be invisible with an ordinary microscope, whereas a smoke...a smoke particle, you know, you can see the smoke particle, you can't see the things that are moving it around, so they must be pretty small. But, I don't think they have any real feeling for an atom, no. I think they think of it as a round blob with a plus and a neutral

sign and a negative going round the outside, you see.

I: But something that's there.

T: Oh, as something that's there, yes. Oh undoubtedly yes. And they appreciate the fact that the atom consists of a part that is movable and a part which is not movable, you know, that you can transfer electrons but you can't transfer the nucleus. Of yes, they see that. But er, a real thing, I mean, I don't know that I see "atom" as a real thing, really. I have no...no conception of what it's like. I think one would have to be more of a mathematician to...to really think of an atom.

The long response to the interviewer's question, "Is an atom a real thing to them?" indicates that although the youngsters may have difficulty grasping the minuteness of this scientific object, the teacher uses words in such manner that it seems that atoms are being presented as real. In order to clarify this, the interviewer states, "But something that's there." And the initial part of the response to this indicates that a Realist view of science is being presented. But this is confounded by the teacher's statement that he has trouble thinking of "atom" as real--the use of "conception" is equally confusing. No further questions on this matter were asked during the interview since it was thought that to do so might seriously influence responses and might, in fact, leave the teacher uncomfortable about the questions raised.

In the seventh lesson, the word "model" was frequently used as youngsters attempted to account for light phenomena according to a particle model. During the lesson, the interviewer judged that an Instrumentalist view of science was being provided for, but this judgment depended upon what was understood by the word "model." Hence the following exchange in the interview:

Interviewer: What do they understand by a model?

Teacher: Well, this is a continuing sort of concept. They, er...we haven't, we're just this time round going in...I've stayed away from the idea that a model is really a mathematical model because mathematics, to them, is a bad word, and I would, you know...well, we didn't do a rigorous development of Inverse Square and I never mentioned Inverse Square--and I won't mention Inverse Square. Because if they go on and they do it in grade eleven, they'll get enough mathematics for it. I only want the idea that the model predicts something, and that something's all right, so the model's good; we can go back and use the model again and get something else out of it. Or, we can come across a phenomenon, light, and go back to the model and say, "Does the model agree with this?" So that right now they have a rather weak idea of what a model is. That, they...they just think it's an idea, er, that, you know...well we developed, er, essentially the Kinetic Theory of Heat without really ever mentioning that it was the Kinetic Theory of Heat until right, right at the end and then I put the word "kinetic" on the... we didn't do any of the math, of course. But we...they're, they're, um,...they've been working with particles all along. And we started out with the atom, so they have some idea, er, particle model of matter. But it's still very vague, and after this section's over I think we'll...when we do the particle model of light and the wave model of light and then they've two very good models --very strong models--that they can compare, they can see some weaknesses in one and strong points of others, and by that time we should have an idea of what a model is. But we're still working on that idea, it's sort of a thing we just sort of come back to once in a while in the course.

From this one can judge that the initial decision that an Instrumentalist view of science is being presented in the lesson is supported.

In the eighth interview, both interviewer and teacher appear to have difficulty in understanding one another. A particular problem with the ontology issue is that overclarifying the question can make the issue so plain that the teacher might feel obligated to respond in a fashion other than he normally would. In the piece that follows, the interviewer found that the questions seemed inadequate for determining the wanted information about context:

Interviewer: I'm interested in the type of understanding the kids have got of how these concepts that we've been talking about fit in. They have from the last lesson power, force, friction, work, potential energy--I write them down so that I don't forget any of them,

and make sure I ask you about them. They're, they're concepts. How do the kids see these? In other words, maybe, what is their understanding of "concept." Is concept something different from other things?

Teacher: I don't know, I don't know. If I can get down and talk to a student face to face, I can get some of these ideas. Largely speaking, I do not know. If a student misses a test, I will talk to him face to face by way of a make-up test. I...I love oral tests. To me I can wring out the information so much better and find out what their ideas are.

I: Do they see, er,...

T: I don't know how to answer it. You've got a good question and I'm not sure at all how to answer it.

I: Well, let me try it from another corner.

T: Yes.

I: Do they see that a concept is something different from something which they, they can see. Well, we can see something being lifted from point A to point B, but we cannot see work.

T: Can you continue...now...

I: Well now...if one is something one can see and one is something not, then there is something special, especially different about the two: one is a concept, one is not. An observation...

T: A reality as opposed to an abstraction.

I: That's the sort of thing. Now, do they make this distinction? Has this been made for them? (Pause) Or do you think they have run them together? Or not worried about it?

T: Well, now there's another possibility too. It could be that they don't worry about them. Certainly the concept of work, they picked it up with no problem--they just recognized there's a rule to be followed. Now that's not always good either, because a rule, blindly memorized, will eventually, I think, lead to problems because later on they find that the rule will not fit in all cases, or cases will appear that don't appear to fit the rule. Students go on memory work--they like to be told. Students like to be told.

During this interchange it became apparent to the interviewer that for the question to be asked, a certain amount of explication was required. As can be seen, the explication coincides with an Instrumentalist view of

science, and the teacher might well have responded in a manner coinciding with what he thought was anticipated. Yet that response was not forthcoming. Instead, the teacher justified his presentation in a quite different, and unexpected, manner. It is interesting to note that the phrasing of the interviewer's final speech deliberately avoids placing the onus upon the teacher and talks instead of pupils making the distinction or having it made for them. An effort was made in all interviews to word questions in this way, in an attempt to alleviate any anxiety teachers might have from thinking that their own efforts were considered by the interviewer to be erroneous or inadequate in some way.

In the eleventh lesson, pupils were required to report observations of electrostatic phenomena, and to refrain from introducing any words referring to things that could not be seen. Since this appeared to imply a view of science corresponding to Instrumentalism, the context was pursued as follows:

> Interviewer: You, in the class at the beginning, were very insistent that the kids just get clear in their minds what the observations are.
>
> Teacher: Umhm.
>
> I: Er, the word "theory" comes up a few times and you say to the kinds, "Well, what are your theories about this?"
>
> T: Um, this is an approach which we've used many, many times, "What theories can we advance here?" And then we try and test them all on the spot if we can. If we can't, we'll try to bring in other observations that we've made at various times or that they have made individually. Er, in a way they're sort of thought experiments, and, er, it's kind of cheating, in a way, but we only have so much time. And, er, by and large we can reject most theories; and if we can't, well, then we have to grapple with it, you see. But I think this is the basic nature of science, that if we have a theory that explains what's going on, then it's a...it's a valid theory, until we can find some observations that the theory cannot explain and then we have to examine it again.

I: So, the youngsters have what sort of...what sort of meaning do they attach to the word theory?"

T: Just an explanation, something that will satisfy the observations, "How can we explain them?" And, er, we've used all kinds of explanations. I tend to be a little facetious sometimes and say, "Well, there's, there's some mystical spirit operating here that just makes it work this way. Now in a case like that this morning with an ebonite rod. It's been rubbed and, er, it exerts...has some effect. We can explain that, and only that, quite satisfactorily in terms of a mystical spirit summoned up out of the rod by the rubbing thereof. Now that explains it.

I: Sure, sure.

T: We can test it and discover further evidence to reject that theory, but we have to start somewhere, you see. Oh, we have a lot of fun in...in getting up some of these theories. The theories of...various theories at various times in science of mystical liquids that have been summoned up to explain all kinds of effects--like light; and, er, we'll get into some of them again in electricity and force, and so forth, and heat energy--one of the more famous ones, the phlogiston theory of heat, this sort of thing.

Irrespective of the error in the last line of this passage, the teacher appears to be providing youngsters with an Instrumentalist view of science, for what is said corresponds to those items of the scheme labelled "Instrumentalist."

In the following excerpt a similar question is asked twice, this device being used in instances when the interviewer was unsure of how natural the teacher's first response was. Here, from the twelfth interview, the interviewer considered the first question to be too direct. The question was asked again in a manner designed to encourage the teacher to speak more, in the hope that his language would illustrate his position more accurately.

Interviewer: Um, right at the end, mention was made of static electricity. What sort of understanding have they got about static electricity?

Teacher: We've taken it in reasonable depth from an experimental

approach. They know that matter consists of positive and negative charges and, as I mentioned, they produced them. And they know the general properties of these charges. And, er, they now call them "protons" and "electrons" and, er, say that atoms contain protons and electrons. Now the reason why I'm going into this is to more or less expand their appreciation of this. They, they recite it--that atoms contain protons, electrons--but I'm a bit concerned that they're not sure, aware of the connection between molecules, atoms, protons, electrons, and the general scale on which these things exist.

I: Umhm.

T: I think probably there's a bit of confusion about just how large a molecule is compared to what an atom is, and how many protons and how many electrons go to make up an individual atom, and what size scale is and how they're...and just the basic make-up. So...

I: But it is presented as a real thing to them.

T: Yes. They, they've seen electrical charges, and, um. I've done a number of experiments with them.

Then later:

I: What do you think their understanding is of an atom? Now this is, er...sort of a sweeping question.

T: Well, as I said before, I'm not sure just exactly how deep it is. I think there's a confusion between atoms and molecules, hence this line of investigation we're going into. Um...I think they're ready to agree that they're small particles. Most of the class...one of the girls, Debbie, has said from time to time that she really doesn't believe there are such things as atoms and molecules and, er...I find that from time to time the class, although they will parrot the fact that there are atoms and molecules, when you ask them...ask them, "What is between the molecules in air?" then they say, "Molecules of something else." "And what are between those molecules?" And, er...they get into the problem of really not being able to visualize the smallest thing. And, and they... they really have trouble with this--that, that, er...we think there is a limit to the minuteness of objects...and they, they just can't see it. They think everything is continuous. And even...

I: Um. Interesting.

T: ...though we produce theories for them, they'll say, "Yes umhm, yes." But then when you start to question them on it they are not quite that positive.

I: Umhm. But the experimental approach that you've been using has been geared to lead up to a particular theory of matter?

T: That's right.

I: And, er, atoms are in fact these particles that are there.

T: Yes. They can say it. I'm not sure whether they really, truly believe it.

The teacher's remarks in this dialogue appear to indicate that a Realist view of science is being provided in his teaching. For example, one would not speak of a pupil "not believing in atoms," if one were not attempting to have pupils arrive at this belief.

Summary.--The excerpts provided above serve to demonstrate the rather complex nature of interviews used in an attempt to obtain indications of the context of each recorded lesson. As can be seen from the variety of questions asked, determination of context by an consistent or standardized protocol, such as testing, was quite impossible. On the other hand, the interviews themselves cannot be construed as objective accounts of context, for they are accounts given by teachers who might have been influenced in some fasion by the proceedings of the interviews. Yet, despite this limitation of these data, they are available to supplement analysis of lessons with important information that could be obtained in no other way.

Format of Data Presentation

The fourteen lessons and their accompanying interviews were transcribed and then typed in a format thought suitable for analysis. In previous work involving lesson analysis, the writer has found it convenient to have the analysis of dialogue appear beside the dialogue.

Thus, the dialogues in every lesson have been typed on one half (the left side) of each page, leaving the other half for analysis. Independent judges then make their analysis opposite the appropriate part of the lesson--the two lessons reproduced in the Appendix have their analyses similarly presented. In order to facilitate the identification of particular passages or lines of dialogue, lines have been numbered in multiples of five, commencing each page with line number one. In all cases, the teacher is identified by "Teacher" and, where possible, pupils have been identified by name, otherwise the term "Pupil" has been used. The dialogue is single spaced with double spacing used to separate speech of different persons.

It can be seen from the transcription of portions of interviews presented above and from the dialogue that appear in the Appendix that punctuation is frequently awkward. In addition to the regular use of punctuation marks, commas and ellipses have been employed to indicate a faltering or a brief pause, apparently resulting from an ongoing and uncorrected change in sentence structure. (Ellipses have also been used to indicate an interruption, when they appear at the beginning or end of a segment of speech. Longer pauses are noted by the word "pause" appearing in parentheses.

During teaching, it is quite usual to find a considerable amount of material presented to pupils that does not appear on a tape recording. Generally this material is in the form of writing on chalk boards. Sometimes, reference is made to charts or to books, and also to phenomena observed by the class. In order that all such material be incorporated in the transcription, it has been placed within parentheses at the

appropriate place.

All these points concerning the presentation of lessons are illustrated in the following excerpt from the second lesson. The commentary on the right-hand side of the page is intended to explain the particular notations used.

In this lesson, the teacher is testing a number of substances with two "probes" attached to a current source and a light bulb, in order to see the degree to which each substance conducts electricity. Pupils discuss conductivity in terms of the bulb's brightness for each substance tested, and then attempt to explain variations they have observed.

Teacher: I want to try some ordinary solids. Right, then. Let's take this one. (Holding up a piece of blue solid) What is this?	The parentheses beginning on L.3 include reference to an important action.
Pupils: Ah. Copper sulfate crystals. Alum.	From the question, no pupils can be identified. Individual comments are separated by periods.
Teacher: Copper sulfate <u>crystals</u>. Note the dry form...	The underlining is intended to reflect the teacher's emphasis.
Pupil: What?	The teacher is interrupted by an unidentified pupil.
Teacher: ...the dry form of copper sulfate. What do you expect? First of all we don't speak of this as being an electrolyte or a non-electrolyte this time--it's not a solution or anything. Is it a conductor or a non-conductor of electricity...	In L.18, the teacher is interrupted by three unidentified pupils
Pupils: Yes. Go ahead. No.	

Teacher: ...in this form?	
Pupils: No, no. Yes.	Two unidentified pupils respond.
Teacher: Brian.	
Brian: I think it will be.	Brian is identified as the pupil called on to respond.
Teacher: You think it will be. (Some comments) Nancy.	Some unidentifiable comments are heard and are depicted as in L.25. Similar comments are heard in L.26.
Nancy: I do. (More comments)	
Teacher: You do too, Ken.	
Ken: No.	
Teacher: There seems to be a little confusion. Maybe we better just try that and see. Now I dried those (pointing to the terminals) quite well, there's no moisture there. (The solid is placed across the terminals and the bulb fails to light. There are many comments from the class.)	The matter is parentheses in L.33 indicates to what the teacher is referring. From L.34 onwards, a description of the test and its outcome is placed in parentheses.

The format and presentation of the interviews are precisely the same as used for the lessons with two exceptions. First, since the interviews are not themselves analyzed but are used to supplement analysis of lessons, they are presented across the full width of the page. Second, since there are only two participants in the interview, they are identified as "T" for the teacher and "I" for the interviewer except for the first time each speaks, as appears in the interview excerpts on previous pages of this section.

Revisions to the Analytical Scheme

This section describes steps taken to ensure that the theoretically derived items of the analytical scheme are in a form that permits identification of classroom discourse with the items. Accordingly, efforts have been made to see that items such as "Evidence is provided in support of claims" have some correspondence with portions of teaching. This initial trial of the scheme was conducted by an analysis of the first two lessons from the series of fourteen collected for the study. As has been shown previously, these lessons were not particularly useful for any other purpose since the interviews were poorly conducted. (In fact, the protocols failed entirely in their mission to derive the context of the lessons.) Nevertheless, the lessons themselves provided useful material upon which the theoretically derived scheme might be tested. As a result of this test, it was found that most of the items seemed potentially useful in their current form, as can be seen by comparing the initial and revised versions of the scheme as they appear in the Appendix.[1] In the following, excerpts from the first two lessons are provided to illustrate the correspondence between selected items and portions of teaching, to indicate points at which certain revisions seemed necessary, and to offer support for the revisions made.

"View of Science" Category Test

The first three examples are taken from the first lesson, and are

[1]The two versions of the scheme, "Initial Analytical Scheme" and "Revised Analytical Scheme" may be found in the Appendix on pp. A2 - A3 and pp. A4 - A5, respectively.

illustrative especially of the test of the first category of the scheme: "View of Science Provided For." Here, pupils were reviewing the results of an experiment designed to illustrate that different sorts of solutions show different electrical conductivities, this being achieved with a light bulb placed in series with two terminals that, when placed in a conducting solution, result in a completed circuit and the lighting of the bulb. Features of the teaching dialogue strongly suggest that the Realist view is being provided for.

> Teacher: ...So, with the acetic acid, it was a poor conductor originally, because, as you said, there are few ions present. As we dilute it with water, we have the formation of more ions.

In this excerpt, the "scientific objects" <u>ions</u> are being talked about as if they have the same ontological status as common-sense objects of perception. Consequently, Item R-b[1] characterizes this piece of dialogue. In the revised version of the scheme, this item is changed slightly to emphasize that it is directed at the manner in which "scientific objects" are presented in class, the revised item reading thus: "'Scientific objects' are talked about as if they have the same ontological status as common-sense objects of perception."

A little further in the same lesson we read:

> Teacher: If we were going to describe a solution of sodium chloride and a concentrated solution of acetic acid, what...or how would you describe it?

> Mike: Both by themselves are not very good conductors, because they don't have many ions. But when you add them with water they become good conductors.

---

[1]This notation refers to item "b" under Realist in the first category of the scheme. Similarly, "I" refers to Instrumentalist, "II" to Intellectual Independence, and "ID" to Intellectual Dependence.

Teacher: Well, this is the question, Mike. I said, "solutions." Okay? We have a <u>solution</u> of sodium chloride and we have a <u>solution</u> of acetic acid.

There are two points of interest here. First, Mike is employing the existence of ions to explain the various conductivities. This, then, supports the accuracy of the use of Item R-b in the previous excerpt. More important, for present purposes, is the second point, that here the teacher honors Mike's response and demonstrates why the response is unacceptable (by indicating that the original question was not being answered entirely). In this way, the teacher can be seen as providing for Intellectual Independence, for this second statement fits Item II-e. This treatment of a pupil's response is different in type from the following:

Teacher: Aqueous sodium chloride will produce--that's what the arrow stands for (in the equation being written)--Joe?

Joe: An electric current strong enough to light the bulb.

Teacher: Right. But what is necessary for that? Joe?

Joe: Er, electrolytes...ions.

Teacher: Okay, ions. All right. What kind of ions would we get?

Pupil: Sodium chloride ions.

Although Joe's responses are honored, no attempt is made to supply reasons for their alleged correctness. (Actually, the first is an inappropriate response to the question.) Thus the passage can be identified as corresponding to Item ID-e. It is also apparent that the Realist view of science is being used here. The teacher is saying, in effect, that one <u>needs</u> ions for this phenomenon to occur. In this case, the theory of ionization is being invoked as a description of phenomena

rather than as an explanation, which appears to fit item R-i of the scheme.

It is not unusual to find one piece of the teaching dialogue describable in terms of more than one item. Thus, in the above excerpt, it is clear that "theoretical statements have the same logical form as observation statements," this being the wording of Item R-a. Thus, this piece might have been characterized as correponding to Item R-a, as well as to R-i. The items are somewhat similar because they are both derived from the Realist view of science. However, the information they contain d ̄fers sufficiently to justify the presence of both items in the scheme.

"Intellectual Independence/Intellectual Dependence" Category Test

The second lesson deals with similar phenomena. Here, however, the teacher is performing the demonstration with circuit, terminals, and solutions, and having pupils make and record observations. Most of the lesson, then, doesn't deal with theoretical claims about the world, but is confined to observations. As a result, there are few examples of aspects of views of science being presented. However, the lesson is quite useful for illustrating the investigator's test of the Intellectual Independence/Intellectual Dependence category of the scheme.

In this first instance, the teacher takes pains to identify the material used.

> Teacher: Now this substance (holding up a beaker) is ordinary tap-water. Just to prove it, I'd better take it out of the tap.

This piece can b^ seen as illustrative of Item II-a, "Evidence is provided in support of claims." In the following portion, the teacher is demanding support for Judy's response and, as well as honoring the

response, is thereby treating it with regard to reason as suggested by Item II-f.

Teacher: Now we're gonna take distilled water. Is this going to be an electrolyte or a non-electrolyte? (Pause) Judy.

Judy: A non-electrolyte.

Teacher: No. It's still water.

Judy: Yes, but...(her response is interrupted by others.)

Teacher: Judy's answering this.

Judy: It's distilled water, though.

Teacher: What's the difference between distilled water and ordinary water?

Here it appears that the teacher is trying to have Judy explicate how distilled water is different from ordinary tap-water; therefore it seems that provision is made for Judy to have her response treated with regard to reason. At this point, it seems that Item II-f usefully describes this portion.

In a later part of the lesson, the teacher attempts to find if some solids conduct electricity, and it is seen that they do not.

Teacher: Now, we've got to figure out why these things aren't working.

Pupil: They aren't organic. (Others comment)

Teacher: Just a minute. Kyle.

Kyle: The connections between all atoms aren't solid. Like in the water, er...the water and all the atoms...sort of fused together.

Teacher: Okay. What does this fusion allow?

Kyle: Electricity to pass through.

Here the teacher is speaking of a theory of matter as if it permits an observation about conduction to be made. Evidently, this can be

characterized by Item R-i, "A model, law, theory, or convention is invoked as a description of phenomena." To make this item more clearly distinctive from the oppostite that appears as I-i, it was decided that the words "description" and "explanation" might be emphasized so that they are made distinctive. Such revisions may be found in the revised version of the scheme.

Generally, arguments in lessons were found to be spread out over a number of pages. In this brief argument, a case is being made for clearning the terminals used in the demonstration.

> Teacher: If I'm going to clean these terminals each time I use a chemical--I think this is especially important isn't it, since some of them are electrolytes, and I could...maybe a little dribble of something would cause a non-electrolyte to become an electrolyte, right? So, I've got to clean them with something.

Interestingly, the argument relies for its completeness upon the point that some contamination of a non-electrolyte might make it behave like an electrolyte. If the situation were reversed, that is the electrolyte might be contaminated by the non-electrolyte, then the argument at this point would not be complete, nor present. Since this last point is not made, this piece of argument may be categorized as absent, and this is in accordance with Item ID-c of the analytical scheme.

Summary

The selection of examples presented above indicates that many items in the scheme are useful in their initial form. But, in addition to revisions noted here, other revisions have been made. One pair of items was deleted entirely. It was found that Items II-b and ID-b appeared to have little direct correspondence with portions of teaching,

and, since the notion of providing means for determining truth is closely dependent upon the presence of evidence and argument, these items seemed redundant. Thus they do not appear in the "Revised Analytical Scheme," the lettering of remaining items being changed to accommodate this deletion. A further pair of items was added: although there was general agreement among pupils about their observations, this raised the point of how possible disagreements among reports of observations might be handled. Generally, this sort of discrepancy might be found to correspond to Items ID-e and II-e of the "Initial Analytical Scheme," according to the fashion in which it is resolved in the teaching. Yet, it was thought that the addition of a further pair of items would make more plain this distinction between ways of handling such disagreement. For this reason, the last pair of items in the "Revised Analytical Scheme" read, "Discrepancies among observations or evidence are resolved rationally" and "Discrepancies among observations and evidence are not resolved on rational grounds."

Two further changes in the wording of items were made. First, Item II-e ("reasons are given for the acceptability of a pupil's statement or response") was changed to include both "unacceptability" and "acceptability" to ensure that users of the scheme focus on the presence or absence of reasons for both correct and incorrect responses. (Item ID-e was changed in a corresponding way.) Second, the word "suggestions" was added to Items II-f and ID-f in the "Initial Analytical Scheme" this pair of items appearing as Items II-e and ID-e in the "Revised Analytical Scheme."

The changes reported in this section satisfied the investigator

that the analytical scheme was suitable for use in analyzing science lessons. Thus, the "Revised Analytical Scheme" was then subjected to use by independent judges in an attempt to estimate its reliability. The procedures adopted in this trial are reported in the following section.

Procedures for Estimating Reliability

The reliability of the scheme was estimated by statistical analysis of judgments made by three independent judges who analyzed a single lesson with the scheme. Since the first two lessons from the series of fourteen collected for this study had been used for revising items of the scheme, as shown in the previous section, the third lesson was used in this reliability test.[1] It was intended that, should this trial yield statistically insignificant results, the scheme would be revised and the trial repeated with the fourth lesson in the series, and so on. However, as shown by the statistical argument in the next section, such repetition was unnecessary for an overall agreement of 82.3 per cent was obtained in the first trial, this being estimated as statistically significant at the .01 level of confidence.

The intention of the reliability test was to have judges use the total scheme to judge portions of teaching according to the intellectual consequences provided for. Because each pair of alternative items in the scheme is used to make such judgments (R-a or I-a, II-c or ID-c, etc.), the reliability trial tests the ability of each pair to discriminate

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[1]This transcribed lesson, together with its accompanying interview, is reproduced as "The Movement of Atoms and Molecules" in the Appendix, pp. A12-A38. The analyses of independent judges appear opposite the classroom dialogue, judges being identified by the letters "A," "B," and "C."

between portions of teaching.[1] (The reliability trial, then, does not test individual items.) Since the credence attaching to measures of reliability is directly proportional to the number of portions of teaching judged, it was decided that each transcribed lesson be divided into several small portions, or "episodes." It can be seen in the Appendix that the lesson "The Movement of Atoms and Molecules" is divided into seventeen such episodes. Were such divisions not made, judges would have to have read and analyzed a total of seventeen lessons and interviews to yield an equivalent number of judgments for this reliability test. The reliability of the total scheme was determined, then, from the judges' characterizations of seventeen portions of teaching.

Since the reliability of the scheme depends on judgments of seventeen episodes (and not on a single judgment about the whole lesson), it is not affected by the places at which the lesson is divided. Yet the divisions of the lesson was not arbitrary at all, for there are several quite distinct divisions in lessons recorded for this study. On two occasions, teachers spent the first part of a lesson concluding previous work, using the second part for introducing a new topic. It will be seen that other divisions have been used, such as different treatments of the same topic (the presentation of phenomena and then attempts at explaining them, for instance), or changes in the style of teaching (lecturing and then questioning, perhaps).

Before the lesson "The Movement of Atoms and Molecules" was

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[1]This ability of pairs of items to discriminate is examined in Chapter VII when attention is given to possible causes for disagreements obtained in this trial.

submitted for analysis by independent judges, the investigator divided it into seventeen episodes and analyzed the lesson himself, the resulting analysis being considered as that of Judge C. Each episode was judged on each of the two categories of the revised scheme: Category 1: Realist/Instrumentalist, and Category 2: Intellectual Independence/Intellectual Dependence. The investigator identified items of the scheme that corresponded to portions of the teaching, these portions being words, phrases, sentences or whole passages. For each episode, the remainder of the lesson and the whole interview was used to support the analysis. Thus, if the interview made valuable contribution to an understanding of the context of the lesson, it was incorporated in the analysis. Once the teaching within an episode was identified according to a number of items from the scheme, a judgment was made about the intellectual provisions of that episode, based upon the predominant part of each category of the scheme as apparent from the analysis. (For instance, if an episode was seen as predominantly representing a Realist view of science. and providing for Intellectual Independence, then the total episode was judged as such.) Since two judgments are made for each episode, the types of judgments are four and are abbreviated as R/ID, R/II, I/ID, and I/II. As can be seen in the Appendix, the judgment for each episode is presented immediately below the beginning of the episode. (Of course, there are portions of teaching that are not amenable to analysis, since the analysis can only be directed toward claims about the world and toward the manner in which they are made and supported in the teaching. Consequently, all teaching dialogue that is concerned with classroom procedural matters is ignored by the analytical scheme; such dialogue is

labelled "procedural only". Episode 17 of "The Movement of Atoms and Molecules exemplifies this point.)

The arrangement of lesson dialogues that confines them to half of each page limits the amount of space available for explicating the analysis. Thus, some straightforward abbreviations were adopted for such purposes as identifying episodes, referring to lines and pages, and noting the item invoked from the scheme to analyze a portion of the dialogue. Episodes are identified by numbers in sequence throughout the lesson, and the beginning of each episode is denoted by "EPISODE" followed by its number and, in parenthesis, the portion of the dialogue constituting that episode. Thus, the caption, "EPISODE 3 (L.38 - p.A14, L.36)" would be found opposite line 38 on page A13, and indicates that Episode 3 begins at this point and carries through to line 36 on page A14. The intellectual consequences provided for by this episode appear immediately beneath this caption. Portions of dialogue that lead to these judgments are identified by line reference followed by an indication of the item of the scheme to which the portion is seen to correspond. Thus, "L.21: ID-d" indicates that the statement commencing on line 21 of the page in question (A13, in this case) is seen to be an instance of "Adequate reasons for the acceptability or unacceptability of a pupil's response are absent"--this item appearing as "d" under "Intellectual Dependence" in Category 2 of the scheme. Similarly, "LL.10-13: I-h" indicates that this passage is seen to be an instance of "The use of a model, law, theory, or convention is signalled"--this item appearing as "h" under "Instrumentalist" in Category 1 of the scheme. Lastly, portions of interviews used to buttress analysis are referred to by the device, "Int.

p. A__ , L. __ ."

When the lesson "The Movement of Atoms and Molecules" had been analyzed in this fasion, two judges were sent all materials necessary for analyzing it independently, with the request that they assist in this portion of the study by following carefully the instructions provided.[1] Judges were also asked to return their completed analyses so that, in the event of serious disagreement, the investigator could locate items appearing problematical, and could revise them accordingly.[2] When the results of this trial were received, they were treated statistically as described in the following section.

Statistical Estimation of Reliability

This section contains a description and analysis of results obtained from the use of the scheme by three independent judges on one lesson. For this test of the reliability of the scheme, the three judges were required to analyze each of the seventeen episodes contained in the third lesson. In all episodes, it was expected that judges could use both categories: Realist/Instrumentalist (R/I), and Intellectual Independence/ Intellectual Dependence (II/ID); accordingly, each episode would be judged "R" or "I", and "II" or "ID". The raw data are presented in

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[1]Materials sent to judges were two copies of "The Movement of Atoms and Molecules." one copy of the accompanying interview, a copy of "Revised Analytical Scheme," an introduction to the study, and a set of instructions for using the scheme. All these materials are reproduced in the Appendix, the last two appearing on pp. A6-A8 and pp. A9-A11 respectively.

[2]The separate analyses of all three judges appear in the Appendix beneath each episode of "The Movement of Atoms and Molecules" to facilitate comparison by the reader.

Table 1. Judgments were obtained for all episodes with the exception of Episode 17. As can be seen from this episode in the Appendix, the matter contained therein appears entirely procedural and, with one exception, the judges agreed that this episode was not amenable to analysis. As is argued later, the slight anomaly presented by this episode is easily handled by the statistical argument and further, the anomaly fails to detract from the statistical significance of the results.

In the following, attention is first given to some statistical descriptions of the data, yielding, among other information, the total percentage of agreement among judges. It is then argued that the statistical significance of this agreement can be estimated using the contingency coefficient, C. The agreements obtained are estimated as statistically significant at the .01 level of confidence.

Descriptive Statistics

The results from the three independent judges appear in Table 1. (Here, the use of a hyphen indicates that an episode is found to contain procedural matter only.) These data are converted to ordinal data in Table 2, where for Category 1 of the scheme, "R" is represented as "1" and "I" becomes "2", and for Category 2, "II" becomes "2" and "ID" becomes "1".[1] In both categories, "0" represents the judgment that an episode contains procedural matter only. An inspection of Table 2

[1]Since ordinal data provide a way of establishing mean scores and mean deviations, the real value of ordinals chosen has no inferential meaning. Further, as shown below, since the statistical significance is found from frequencies of 1's and 2's appearing in the ordinal data, the ordinals chosen to represent judgments cannot affect calculations of statistical significance.

TABLE 1

RAW DATA FROM THE THREE INDEPENDENT JUDGES
ANALYZING A LESSON

Category 1: Realist/Instrumentalist (R/I)				Category 2: Intellectual Independence/Intellectual Dependence (II/ID)			
	Judge				Judge		
Episode	A	B	C	Episode	A	B	C
1	R	R	R	1	ID	ID	ID
2	R	R	I	2	ID	ID	ID
3	R	R	I	3	ID	ID	II
4	R	R	R	4	ID	ID	ID
5	R	R	R	5	ID	ID	ID
6	R	R	R	6	II	ID	II
7	R	R	R	7	ID	ID	ID
8	R	R	R	8	ID	ID	ID
9	R	R	R	9	ID	ID	ID
10	R	R	R	10	ID	ID	ID
11	R	R	R	11	II	ID	ID
12	R	R	R	12	II	ID	ID
13	R	R	R	13	ID	ID	II
14	R	R	R	14	II	ID	II
15	R	R	R	15	ID	ID	ID
16	R	R	R	16	ID	ID	ID
17	R	-*	-	17	-	-	-

*The hypen indicates that judges found an episode to contain procedural matter only.

TABLE 2

ORDINAL DATA OF THE THREE INDEPENDENT JUDGES

Category 1: Realist/Instrumentalist (1/2)				Category 2: Intellectual Independence/Intellectual Dependence (2/1)			
	Judge				Judge		
Episode	A	B	C	Episode	A	B	C
1	1	1	1	1	1	1	1
2	1	1	2	2	1	1	1
3	1	1	2	3	1	1	2
4	1	1	1	4	1	1	1
5	1	1	1	5	1	1	1
6	1	1	1	6	2	1	2
7	1	1	1	7	1	1	1
8	1	1	1	8	1	1	1
9	1	1	1	9	1	1	1
10	1	1	1	10	1	1	1
11	1	1	1	11	2	1	1
12	1	1	1	12	2	1	1
13	1	1	1	13	1	1	2
14	1	1	1	14	2	1	2
15	1	1	1	15	1	1	1
16	1	1	1	16	1	1	1
17	1	0*	0	17	0	0	0

*A zero indicates that judges found an episode to contain procedural matter only.

suggests that there is considerable agreement amongst judges on each episode. There are, however, certain deviations from perfect agreement as can be seen by examining the ratings for Episode 3. The mean score for each judge, and the mean deviation are given in Table 3. Separate calculations are provided for the exclusion and inclusion of Episode 17, this episode only contributing 1/17 of the total data.

A computation of the mean and mean deviation for each episode yields an indication of the amount of departure from an estimated "true" score for each episode by the three judges. These figures appear in Table 4, for information. (They are not used for computing the percentage of agreement or for estimating significance.)

Lastly, the percentage agreement amongst judges for each category of the analytical scheme can be reported. The total number of possible agreements in a category is three for each episode (A agrees with B, A agrees with C, B agrees with C). Accordingly, the percentage of agreement is given by the relationship:

$$\text{Percentage of agreement} = \frac{\text{Number of agreements obtained}}{3 \times \text{Number of episodes}} \times 100$$

the numerator being the sum of the number of agreements between each pair of judges. Thus for Category 1 (R/I), the percentage of agreement for 16 episodes is:

$$\text{Percentage of agreement} = \frac{16 + 14 + 14}{3 \times 16} \times 100 = \frac{44}{48} \times 100 = 91.7\%$$

For 17 episodes:

$$\text{Percentage of agreement} = \frac{16 + 15 + 14}{3 \times 17} \times 100 = \frac{45 \times 100}{51} = 88.2\%$$

The percentage of agreements for Category 2 (II/ID) are found similarly.

For 16 episodes:

$$\text{Percentage of agreement} = \frac{12 + 12 + 12}{3 \times 16} \times 100 = \frac{36}{48} \times 100 = 75\%$$

For 17 episodes:

$$\text{Percentage of agreement} = \frac{13 + 13 + 13}{3 \times 17} \times 100 = \frac{39}{51} \times 100 = 76.5\%$$

The judgements using the analytical scheme are more consistent in Category 1 than in Category 2.

The more conservative value of the total percentage of agreement for the whole scheme is obtained by averaging the percentages of agreement for each category over 17 episodes.

$$\text{Total percentage of agreement} = \frac{88.2 + 76.5}{2} = 82.3\%$$

The statistical significance of these percentages of agreement is estimated below using inferential statistics.

TABLE 3

MEAN AND MEAN DEVIATION FOR EACH JUDGE

Category 1: Realist/Instrumentalist

for 16 episodes:

	Judge A	Judge B	Judge C
ΣX	16	16	18
$\overline{X}$	1	1	1.125
D	0	0	.219

for 17 episodes:

	Judge A	Judge B	Judge C
ΣX	17	16	18
$\overline{X}$	1	.942	1.058
D	0	.11	.221

Category 2: Intellectual Independence/Intellectual Dependence

for 16 episodes:

	Judge A	Judge B	Judge C
ΣX	20	16	20
$\overline{X}$	1.25	1	1.25
D	.375	0	.375

for 17 episodes:

	Judge A	Judge B	Judge C
ΣX	20	16	20
$\overline{X}$	1.175	.942	1.175
D	.387	.11	.387

TABLE 4

MEAN AND MEAN DEVIATION FOR EACH EPISODE

Category 1: Realist/Instrumentalist				Category 2: Intellectual Independence/Intellectual Dependence			
Episode	ΣX	$\bar{X}$	D	Episode	ΣX	$\bar{X}$	D
1	3	1	0	1	3	1	0
2	4	1.3	.44	2	3	1	0
3	3	1	0	3	4	$1.\dot{3}$	.44
4	3	1	0	4	3	1	0
5	3	1	0	5	3	1	0
6	3	1	0	6	5	$1.\dot{6}$	.44
7	3	1	0	7	3	1	0
8	3	1	0	8	3	1	0
9	3	1	0	9	3	1	0
10	3	1	0	10	3	1	0
11	3	1	0	11	4	$1.\dot{3}$	.44
12	3	1	0	12	5	$1.\dot{6}$	.44
13	3	1	0	13	4	$1.\dot{3}$	.44
14	3	1	0	14	5	$1.\dot{6}$	.44
15	3	1	0	15	3	1	0
16	3	1	0	16	3	1	0
17	1	$.\dot{3}$	.44	17	0	0	0

Inferential Statistical Analysis

The purpose of the inferential statistical analysis is to estimate the statistical significance of agreements obtained between pairs of judges. The argument, in essence, is to assume that there is no association between the ratings of pairs of judges, and to test this assumption (the null hypothesis).

There is no rigorous way to treat these data. However, an estimated value of statistical significance can be obtained by using the contigency coefficient, C. As noted by Siegel, C is the appropriate statistic for measuring the extent of association between two sets of data when the data are categorical.[1] (For interval data, a Pearson r would be suitable.) The contingency coefficient is given by the relationship:

$$C = \sqrt{\frac{\chi^2}{N + \chi^2}}$$

This relationship between C and chi-square (χ^2) provides a convenient way of estimating the level of confidence with which the null hypothesis is rejected.

The value of χ^2 for a 2 x 2 contingency table is computed from the function:

$$\chi^2 = \sum_{i = j}^{2} \sum_{j = 1}^{2} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

[1]Sidney Siegel, Nonparametric Statistics for the Behavioral Sciences (New York: McGraw-Hill, 1956), p. 196.

where O_{ij} is the observed frequency in the ith. row of the jth. column, and E_{ij} is the expected frequency (under the assumption that there is no association) for the same cell.[1]

The calculations of C and χ^2 for pairs of judges using Category 1 (Realist/Instrumentalist) over sixteen episodes are given in Table 5. (Episode 17 is ignored here, but is considered below). The expected frequencies (E_{ij}) are derived from the assumption that there is no association between the ratings of judges. That is, an equal distribution of the sixteen ratings is expected (four in each cell). Since the observed frequencies are small, Yates' correction for continuity is applied.[2] (Obtained frequencies which are greater than expected frequencies are reduced by .5, those less than expected frequencies are increased by .5. This correction decreases the value of χ^2.)

The null hypothesis is that there is no association between the ratings by pairs of judges. This hypothesis is rejected at the .01 level of confidence if values of χ^2 exceed 6.64. The null hypothesis is rejected for all pairs of judges in Table 5, thus the values of C are statistically significant at the .01 level of confidence.[3]

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[1] Ibid.

[2] J.P. Guilford, Fundamental Statistics in Psychology and Education (New York: McGraw-Hill, 1965), p. 237.

[3] The upper limit of C is given by Siegel as .707. (Siegel, op. cit., p. 201.) Many values of C derived below are greater than this value. Also, as Siegel notes, χ^2 cannot be calculated when more than twenty per cent of expected frequencies are less than five. However, the investigator's use of C with expected frequencies of four provides a way of estimating statistical significance, and this is the only way to obtain such an estimate. Despite these two limitations, Siegel notes that C provides a useful indication of association. (Ibid.)

TABLE 5

CALCULATION OF χ^2 AND C FOR CATEGORY 1 OVER 16 EPISODES

		Judge B	
		2	1
Judge A	1	(4)* 0	(4) 16
	2	(4) 0	(4) 0

χ^2 = 45.3 ($p<.001$)

C = .86

		Judge C	
		2	1
Judge A	1	(4) 2	(4) 14
	2	(4) 0	(4) 0

χ^2 = 29.3 ($p<.001$)

C = .80

		Judge C	
		2	1
Judge B	1	(4) 2	(4) 14
	2	(4) 0	(4) 0

χ^2 = 29.3 ($p<.001$)

C = .80

* Expected frequencies are given in parentheses.

TABLE 6

CALCULATION OF χ^2 AND C FOR CATEGORY 2 OVER 16 EPISODES

		Judge B 2	Judge B 1
Judge A	1	(4) 0	(4) 12
	2	(4) 0	(4) 0

$\chi^2 = 26.3 \quad (p<.001)$

$C = .79$

		Judge C 2	Judge C 1
Judge A	1	(4) 2	(4) 10
	2	(4) 2	(4) 2

$\chi^2 = 9.8 \quad (p<.01)$

$C = .62$

		Judge C 2	Judge C 1
Judge B	1	(4) 4	(4) 12
	2	(4) 0	(4) 0

$\chi^2 = 26.3 \quad (p<.001)$

$C = .76$

The ratings of judges using Category 2 (Intellectual Independence/ Intellectual Dependence) are treated in the same way, in Table 6. Again, the null hypothesis is rejected in each case.

The values of C and χ^2 computed in Tables 5 and 6 are for the first sixteen episodes of the lesson. But, as seen in Table 1, there are seventeen episodes. (Judge A rated Episode 17 as "R" for Category 1 of the scheme. In all other instances, this episode was rated "procedural.") It is clear that Episode 17 must be taken into account in order to derive a complete estimate of the statistical significance of the ratings obtained from judges.

The total seventeen episodes can be accounted for by considering that each judge can make <u>three</u> ratings, not two. The third rating would be to judge an episode as "procedural." A 3 x 3 contingency table is necessary to determine the contingency coefficients under these circumstances.

Quantitatively, it is difficult to calculate values of C in 3 x 3 contingency tables from the obtained data. The expected frequencies (seventeen) have to be evenly spread over nine cells, so they are small. (Qualitatively, of course, it is apparent that the data increases in significance if the number of possible choices increases.) However, a <u>conservative estimate</u> of values of C (and χ^2) can be obtained by collapsing the 3 x 3 contingency tables into 2 x 2 contingency tables. Guilford advises that the data be collapsed so that additional frequencies are added to smaller frequencies.[1] In this way, the value of χ^2 is reduced.

[1]Guilford, <u>op</u>. <u>cit</u>., p. 241.

Table 7 shows the collapsing of the 3 x 3 contingency table for Category 1 over seventeen episodes. Values of χ^2 and C are calculated as before. (The expected frequencies have been increased from 4 to 4.25, since there are now seventeen ratings to be distributed evenly among the cells.) Table 8 shows the treatment of data for Category 2 over seventeen episodes.

It can be seen from Tables 7 and 8 that in each case the null hypothesis is rejected at the .01 level, even though the more conservative estimate of χ^2 is used. Consequently, the null hypothesis that the ratings of judges have no association is rejected. Instead, the statistical treatments suggest that the scheme has been used reliably, because the association between ratings by judges has been estimated to be statistically significant (given the limitations of this procedure, noted above).

Summary

Procedures used in revising the initial version of the analytical scheme and in determining the reliability of the revised version have been reported in detail in this chapter. Special attention was given to protocols of interviews conducted to establish the context of lessons. The results of the reliability trial with three independent judges were found to yield an overall agreement of 82.3 per cent, and the agreements obtained between each pair of judges were estimated to be statistically significant at the .01 level of confidence. Accordingly, a further revision of the scheme and a repeat reliability trial were unnecessary.

TABLE 7

CALCULATION OF χ^2 AND C FOR CATEGORY 1 OVER 17 EPISODES

Judge A (rows) × Judge B (columns)

Judge A	2	1	0
0	0	0	0
1	0	16	1
2	0	0	0

	2	1
1	(4.25) 0	(4.25) 16
2	(4.25) 0	(4.25) 1

χ^2 = 38.2 (p<.001)

C = .85

Judge A (rows) × Judge C (columns)

Judge A	2	1	0
0	0	0	0
1	2	14	1
2	0	0	0

	2	1
1	(4.25) 2	(4.25) 14
2	(4.25) 0	(4.25) 1

χ^2 = 25.9 (p<.001)

C = .78

Judge B (rows) × Judge C (columns)

Judge B	2	1	0
0	0	0	1
1	2	14	0
2	0	0	0

	2	1
1	(4.25) 2	(4.25) 14
2	(4.25) 1	(4.25) 0

χ^2 = 25.9 (p<.001)

C = .78

TABLE 8

CALCULATION OF χ^2 AND C FOR CATEGORY 2 OVER 17 EPISODES

		Judge B		
		2	1	0
Judge A	0		0	
	1	0	12	4
	2	0	0	0

1	(4.25) 0	(4.25) 12
2	(4.25) 1	(4.25) 4

$\chi^2 = 17.6$ ($p<.001$)

C = .71

		Judge C		
		2	1	0
Judge A	0	0	0	1
	1	2	10	0
	2	2	2	0

	2	1
1	(4.25) 2	(4.25) 10
2	(4.25) 3	(4.25) 2

$\chi^2 = 8.0$ ($p<.01$)

C = .56

		Judge C		
		2	1	0
Judge B	0	0	0	1
	1	4	12	0
	2	0	0	0

	2	1
1	(4.25) 4	(4.25) 12
2	(4.25) 1	(4.25) 0

$\chi^2 = 17.6$ ($p<.001$)

C = .71

The lesson used in the reliability determination, "The Movement of Atoms and Molecules" is appended.[1] For the convenience of the reader, the separate analyses of the independent judges are presented so that characterizations within each episode may be compared. As can be seen, this is achieved only by sacrificing the placement of each analysis opposite the appropriate portion of the discourse; accordingly, the analysis of "The Movement of Atoms and Molecules" does not readily show the use of the scheme, although complete line and page references are provided to assist in identifying passages to which each piece of analysis belongs.[2] To clearly demonstrate arguments used in characterizing portions of teaching according to items of the scheme, the Appendix contains a second transcribed lesson, its accompanying interview, and an analysis performed by the writer.[3] This lesson, titled for present purposes "A Particle Model of Light," is the seventh in the series recorded for this study. It was chosen for inclusion in this document since it clearly provides for quite the opposite consequences to those provided by "The Movement of Atoms and Molecules." The appended lessons, then, exemplify the use of the analytical scheme in analyzing two distinct types of science teaching.

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[1] The transcription of "The Movement of Atoms and Molecules" may be found on pp. A12-A31.

[2] It can be seen that Judges A and C have provided reasons for their analyses in many instances, although this was not required of them. This additional information is most useful, as it happens, in seeking explanations for the disagreements found among judges, as attempted in Chapter VII.

[3] The second lesson, "A Particle Model of Light" is reproduced with the accompanying interview on pp. A39-A68.

In the following chapter, attention is given to the limitations of the scheme (relying upon possible sources of disagreement among judges), its usefulness, and its promise for further investigations into the potential of science teaching.

CHAPTER VII

CONCLUSION AND DISCUSSION

The study is concluded in this chapter. In the first section, the problems and the purposes of the study are recalled and the theoretical and empirical components are reviewed. The investigator's central purpose was to derive an analytical scheme and estimate the reliability with which it could be used. Disagreements among independent judges using the scheme suggest that it has some practical limitations. These disagreements are therefore examined in detail, in the second section of this chapter. The final section contains implications of the study for further research and for supervision of science teaching.

Review of the Study

This study has been an investigation into selected characteristics of science teaching: the potential of science lessons for influencing a pupil's understanding of different views of science, and for fostering Intellectual Independence or Intellectual Dependence. (The latter set of alternative consequences refers to potential consequences for pupils of different ways in which knowledge claims are supported in science lessons.) The importance of investigating these characteristics has been demonstrated; an analytical scheme for detecting them has been derived, and its reliability has been estimated.

Problems and Purposes

The major problem for this study was that neither of the two predominant ways of investigating teaching has generated conceptual devices needed to examine consequences of science teaching which are this investigator's concern. It has been shown that available devices for analyzing classroom discourse do not focus on either (1) the provision which influences pupils' understanding of science or (2), the provision made for consequences defined as Intellectual Independence or Intellectual Dependence. Also, the examination of these consequences by achievement measures is not feasible. To begin with, appropriate measuring instruments are not available. Even if they were, the use of achievement measures to make claims about consequences of teaching requires evidence that measured consequences are indeed consequences of, or correlations to, teaching. Such evidence can be obtained only by a simultaneous analysis of teaching and achievement.

The corollary to the problem for this study was that one cannot examine instances of teaching, to see what provisions are being made by certain characteristics of its discourse, unless an observation scheme for doing so is available.

Accordingly, the purpose of this study was stated as twofold: first, to demonstrate the significance of certain intellectual consequences of science teaching (which cannot be investigated by available products of predominant research approaches); and second, to produce an analytical scheme for detecting with reasonable reliability whether or not provision is made for these consequences in classroom discourse.

The Theoretical Component

The theoretical component of this study led to the development of the Initial Analytical Scheme,[1] which consists of two categories of theoretically derived items. The categories focus on two quite distinct types of intellectual consequences. Category 1 contains items for detecting the view of science provided in teaching, Realism or Instrumentalism. Category 2 contains items for detecting the provision for Intellectual Independence or Intellectual Dependence.

Chapters III and IV showed the significance of different ways to view science, and led to the derivation of the first category. Chapter V showed the significance of the consequences Intellectual Independence and Intellectual Dependence, and led to the derivation of the second category.

Arguments in Chapter III showed that scientific explanation can be viewed in two ways: the Deductive Paradigm and the System Paradigm. Each paradigm was examined to reveal how each implies a different view of the scientific enterprise (as the way to explain, or as a way to explain), and to discuss the implications of these views in terms of how one might view the world. The distinctions between the Deductive and System Paradigms are therefore most significant so far as their implications for pupils are concerned. Yet, the two paradigms alone were not found adequate for deriving items to detect such distinctions within classroom discourse. In Chapter IV, therefore, different views about

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[1]The Initial Analytical Scheme is reproduced in full on pp. A2-A3 of the Appendix.

the status of theories and "scientific objects" (ions, charges, etc.) were discussed to show that the views Realism and Instrumentalism imply different ways of speaking about theories, "scientific objects," and explanations. Nagel's account of Realism and Instrumentalism[1] was used to establish features of each view, and excerpts from two science lessons were used to determine that these features are suitable for identifying the provision made in each portion of the teaching. The features of Realism and Instrumentalism were then arranged as alternative items of the first category of the analytical scheme, "Category 1: View Of Science Provided For."

The second category of the scheme, focusing on the notions of Intellectual Independence and Intellectual Dependence, was developed in Chapter V. Here it was shown that the way in which knowledge claims are supported in teaching effectively governs the degree to which pupils are enabled to judge the truth of claims independently of a teacher. As demonstrated, potential consequences of various presentations of evidence and/or argument in teaching are significant in that they bear directly on pupils' acquiring knowledge or belief. So, the theoretical framework for this way of investigating classroom discourse appeared to be related to epistemological considerations. Accordingly, the analysis in Chapter V began with an account of the traditional conditions of knowledge as treated by Scheffler.[2] But the conditions of truth and evidence

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[1]Nagel, The Structure of Science, op. cit.

[2]Scheffler, Conditions of Knowledge, op. cit.

presented difficulties. These were resolved by postulating the consequences "Intellectual Independence" and "Intellectual Dependence" as ways of capturing potential consequences of epistemological features of classroom discourse.

Recent work in the area of philosophical analysis of "teaching" was examined to show that the notions of Intellectual Independence and Intellectual Dependence are quite clearly related to characterizations of teaching and indoctrinating, respectively. And so, features which conceptually discriminate between "teaching" and "indoctrination" were incorporated into the notions of Intellectual Independence and Intellectual Dependence. In this way, the second category of the analytical scheme was derived, "Category 2: Provision For Intellectual Independence Or Dependence."

The Empirical Component

The empirical component of the study provided the basis for claiming that the analytical scheme could be used with reasonable reliability for detecting intellectual consequences provided in teaching.

Data for the empirical component consisted in part of a series of fourteen grade 9 and 10 science lessons. Since the potential of any lesson has been shown to depend on the context in which it is given (and thus, understood), interviews were conducted with teachers following their lessons to provide information about context, where this was not evident from the lessons themselves.

The first two lessons were analyzed by the investigator using the Initial Analytical Scheme. Revisions were made to this version of

the scheme where it was evident that theoretically derived items were unclear or failed to discriminate usefully. The Revised Analytical Scheme was generated from these revisions.[1] This version was used in the reliability estimate.

To show that the scheme could be used reliably, the third lesson, "The Movement of Atoms and Molecules,"[2] was submitted with its corresponding interview (and a set of instructions) for analysis by three independent judges. Results from these analyses yielded an overall agreement of 82.3 per cent. No rigorous method is available for testing precisely the statistical significance of this percentage of agreement. If the data were interval, a Pearson $\underline{r}$ could be computed, assuming no association between ratings of pairs of judges, and the significance of the correlation could be determined. Since the data are nominal, the contingency coefficient (C) is appropriate.[3] Despite two limitations of this statistic for treating the data at hand, as noted above, it was used nevertheless as an estimate of inter-judge reliability of the scheme. The estimate is that reliability between pairs of judges is statistically significant at the .01 level of confidence.

Since the arrangement of the judges' separate analyses of this lesson was not thought to be a clear demonstration of the use of the scheme, the seventh lesson was analyzed by the investigator and included

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[1]The extent of these revisions can be seen by comparing the versions of the schemes on pp. A2-A5 of the Appendix.

[2]This lesson, the three analyses, and the interview conducted after the lesson appear on pp. A12-A38 of the Appendix.

[3]Siegel, _op. cit._

in the Appendix. This lesson, "A Particle Model of Light," was chosen since it provides for quite different intellectual consequences than does the third lesson. The analysis of this lesson shows the way in which the analytical scheme is used.[1]

Summary

This study has demonstrated the significance of investigating classroom discourse for the view of science provided and for the provision of Intellectual Independence or Intellectual Dependence. An analytical scheme for detecting these provisions was derived from theoretical considerations. Furthermore, it has been shown that the scheme can be used reliably for analyzing science teaching. Accordingly, the purposes set for the study have been achieved.

As discussed in the following section, an interesting finding emerged from the empirical component of the study, although it had not been predicted. The third lesson, which was characterized predominately as providing for a Realist view of science, was also characterized as providing predominately for Intellectual Dependence. Contrariwise, the seventh lesson, which was characterized predominately as providing for an Instrumentalist view of science, was also characterized as providing predominately for Intellectual Independence. This finding raises the question of possible correlations between Realism and Intellectual Dependence,

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[1]The lesson "A Particle Model of Light" and its analysis appear on pp. A39-A68.

and between Instrumentalism and Intellectual Independence. While the investigation of that question is beyond the scope of this study, it is certainly an implication for further research.

Power and Limitations of the Analytical Scheme

Two major points are addressed in this section: the usefulness of what can be detected when using the scheme to analyze science teaching, and the limitations of the scheme, both from a theoretical point of view and as evident from disagreements among judges in the reliability estimation. In part, then, this section addresses the corollary to the problem, as well as the achievement of the study's purposes. In the first part of the section, it is shown that the analytical scheme allows one to detect important provisions made by the two lessons in the Appendix. Then the limitations of the scheme are discussed in two subsequent sections.

The Power of the Analytical Scheme

In Chapter II, it was shown that there are no devices available for detecting what this investigator has shown to be significant intellectual provisions made by teaching. Specifically, current analytical devices are not designed to detect views of science provided in teaching, nor to discriminate between the provision to foster Intellectual Independence or Intellectual Dependence. As evidenced by analyzed lessons in the Appendix, the scheme developed in this study can be used to detect characteristics of teaching related to these consequences. Moreover, the two lessons in the Appendix are seen to provide for importantly different consequences.

The first lesson, "The Movement of Atoms and Molecules," is characterized by the judges as providing predominately for the Realist view of science and for Intellectual Dependence. Accordingly, by drawing upon arguments made earlier in this study, one can speak quite specifically about the potential consequences of this lesson for pupils.

The way in which "molecules" are spoken of as existing suggests, logically, that there can be no other way of explaining these phenomena. Thus science can be seen to have successfully and finally terminated its enquiries into this area. (Also, of course, previous attempts at explaining these phenomena must have been false.) The language of these implications suggests that science proceeds by something similar to an inspection of reality, and that truth, for science, is a matter of determining what the world is made of. Accordingly, the lesson provides for the view that science is the way of explaining the world, and the legitimacy of other ways to explain is precluded.

From Table 1, it can be seen that judges found this lesson to provide for Intellectual Dependence, predominately. That is, the teaching leaves pupils largely dependent upon the teacher for judgments about the truth of claims made in the lesson. Pupils are not provided with an understanding of the conditions by which the truth of claims is judged, nor are the arguments supporting such claims made available to them, in the majority of cases. Neither have pupils the opportunity to judge the appropriateness of theories or explanations against alternative ones. In short, the lesson does not provide pupils access to the intellectual underpinnings of what is presented in the discourse.

Quite different intellectual consequences are provided for by the second lesson, "A Particle Model of Light." Using the analytical scheme, the investigator has revealed that the view of science provided by this lesson is Instrumentalism. Furthermore, ten out of the sixteen episodes have been characterized as providing for Intellectual Independence.

By making it clear that a model is to be derived to explain phenomena, the teacher in this lesson is making provision for the understanding that models are conceptual, not real, and that science progresses by inventing conceptual devices to explain. This view does not preempt the possibility that investigations in this area are incomplete. Indeed, since the model is to be judged according to its adequacy, it is logically possible that it will be found inadequate. Once science is presented as _a_ way of explaining, rather than as _the_ way of explaining the world, the teaching further allows for the possibility of explaining phenomena in terms other than scientific ones.

In a number of cases, pupils in "A Particle Model of Light" are permitted to engage in the intellectual processes which lead to the substantiation of knowledge claims. For instance, the teaching makes provision for the understanding that the model is to be judged in a particular way. Thus pupils are not dependent entirely upon the teacher for judgments about the truth of claims. Instead, they are provided with conditions necessary for making these judgments themselves.

So, "A Particle Model of Light" provides for consequences quite different from those provided by "The Movement of Atoms and Molecules."

These differences cannot be detected without a device such as the scheme developed in this study. And, since the potential consequences detected as provisions made by teaching are of fundamental significance to pupils, the investigator finds that the Appendix provides adequate demonstration of the power of the analytical scheme.

Theoretical Limitations of the Analytical Scheme

This study is limited by the fashion in which the problem of analyzing teaching has been addressed. Concentrating upon the potential of teaching necessarily precludes consideration of what might indeed be the actual consequences of teaching. Of course, the total endeavor of the study has been directed at showing that one can describe lessons with reasonable reliability according to their intellectual provisions, thus this limitation in no way jeopardizes the validity of claims made here, nor of claims made about the two analyzed lessons. Instead, the limitation firmly prescribes the type of claim that can be made about lessons through use of the scheme. Claims must be analytical, and not empirical.

In a similar manner the study is limited by the conceptual frameworks selected for examining lessons. A focus upon views of science and the fostering of Intellectual Independence or Dependence rules out any investigation into other features of science lessons that might be important. Nevertheless, within the boundaries imposed by these limitations, the study has resulted in a compact set of clues for making claims about two important intellectual consequences provided for in science teaching.

Practical Limitations of the Analytical Scheme

From Table 1, it is evident that there is disagreement among independent judges about the characterization of Episodes 2, 3, 6, 11, 12, 13, 14, and 17 in "The Movement of Atoms and Molecules." The disagreements occur in one or other, or both, categories of the scheme. Because they suggest practical limitations in using the scheme, the disagreements are viewed as important and are discussed below.

It is found that disagreements might best be accounted for in terms of the following four problems. First, it is clear that some of the instructions for using the scheme require clarification. In particular, the criterial attributes of "procedural matters" are lacking in specificity. Furthermore, there appears to be some need for stating that pupils' contributions are to be taken as part of the teaching discourse, whereas questions are not amenable to analysis. (Questions are not propositional knowledge claims.)

Second, in a number of cases, conflicting characterizations appear in the same episode. For instance, parts of an episode might be characterized as "ID," and others as "II." So, judges have to "weight" such conflicting characterizations in order to make an overall characterization of the episode. It appears that judges have "weighted" these differently. This is not surprising for no guidance as to "weighting" is offered in the instructions. Indeed, since the scheme is qualitative and not quantititive, no guidance as to "weighting" can be offered. This limitation of the scheme cannot be resolved without some empirical determination of the relative impacts of features of teaching detected by the

scheme; that is beyond the scope of this study.

The second problem may be related to the third: that the instructions do not specify the size of portions of teaching which are to be analyzed. For instance, a single statement might be characterized in one way but the argument in which the statement appears might be characterized quite differently.

Fourth, some disagreements between judges can be accounted for in terms of items of the scheme which are somewhat unclear. It will be seen below, for instance, that Items II-d and ID-e seem not to communicate clearly. Moreover there are indications that Item II-a is ambiguous. It needs to be stated that this item <u>can</u> be used to characterize a reference to evidence presented in previous lessons. The item is not intended for characterizing the presence (or absence, using "ID-a") of statements which support the claim that evidence <u>has been</u> presented in previous lessons. (Since the latter is a question of context, it can be determined from the interview protocol.)

These limitations appear to explain disagreements among judges. Thus, the points mentioned above would require attention in further uses of the analytical scheme.

Episodes in which disagreements occur are discussed below.[1]

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[1]In the discussion of the disagreements, it will be noted that judges have sometimes used different items of one alternative in a given category of the scheme and have, nevertheless, arrived at identical judgments. Thus, one judge might have used "R-a" to describe a statement, whereas another judge used "R-b," yet both judges arriving at the overall description "R" for the episode in which that statement is located. Such discrepancies are insignificant for, it will be recalled, items in the scheme are used to discriminate between the two alternatives presented by each category of the scheme. So, the relevant consideration is if the judges can discriminate between "R-a" and "I-a," or between "R-b" and "I-b," in the above example.

Episode 2 (p. A13, LL. 10-38).--The characterization of LL. 10-13 appears to be responsible for the disagreement in this episode. Here Judges A and C read the statement as indicative of Instrumentalism, whereas Judge B disagrees. It seems that items are not discriminating here. However, this cannot be the cause of the disagreement, for it is Judge C who classifies the episode as "I ," whereas the others judge it "R." Thus it is likely that the importance or weight attached by judges to individual characterizations is the source of the disagreement. It can be seen, for instance, that Judge A regards the occurrence of "I-a" in LL. 10-13 to be of lesser significance than the three instances of "R-h" detected in the remainder of the episode. This variation in weighting might be related to the influence of the total context of the lesson (as evident in the interview) upon characterizing each episode. Judge A, for example, characterizes each episode as "R," so it is quite reasonable that little significance is attached to this single instance of "I-a." Different weighting might account for Judge C's disagreement with the other judges.

Episode 3 (p. A13, L.38-p. A14, L.36).--This is the only episode in which there is disagreement in both categories of the scheme. The disagreement in Category 1 appears similar to that in the previous episode. Both Judges A and C note that a convention is stipulated in LL. 4-9 (p. A14), yet apparently assign different significance to this feature. Also of note is Judge B's analysis which finds this segment corresponding to "R-a." Here, then, is a case where an item is not discriminating as required, this suggesting that it might be in need of clarification in later versions of the scheme. A consequence of focusing upon different

lengths of portions of an episode is illustrated in Judge C's analysis of LL. 22-36. The reasons for his finding this portion "II-a" are stated, and it is significant that, in characterizing LL. 18-36, both of the other judges appear to have focused upon a different feature of the discourse (it doesn't provide for consideration of alternative explanations). It is possible that a precise specification of the size or type of portions to be analyzed would eliminate this problem.

Episode 6 (p. A16, L. 13-p. A17, L. 17).--This is another instance in which disagreement might be a consequence of assigning different weights to items. For instance, Judge A attached considerable importance to the provision of evidence in the reference to a previous experiment in LL. 13-23. Judge B contradicts this finding in his analysis. A possible explanation for this difference is that Judge B was looking for evidence to support the assertion that an experiment was performed and Judge A was noting that evidence was provided previously. If it were made clear that Item II-a can be used for characterizing a mention of evidence presented on a previous occasion, this difficulty might not have arisen. The scheme might be improved, then, by clarifying Item II-a.

A further feature of Judge B's analysis is the use of "ID-b" and "ID-c" in LL. 3-8 (p. A17) for a question. However, "Correspondence of diagram or model to phenomena is not demonstrated by evidence or by argument" and "Adequate reasons for the acceptability or unacceptability of a pupil's response are absent" are not applicable to questions, but are only applicable to statements. This difficulty might be obviated by a

clearer indication in the instructions that the scheme is for statements and portions of arguments, and that questions are not amenable to analysis.

As noted beforehand, more than one item may be applicable to a given portion of the discourse. This feature of the scheme might lead to some difficulties, and an example is available in this episode. In LL. 9 (p. A17), "All right" is found inadequate by Judge B, yet Judge A has focused on another aspect of the teacher's response in which the pupil's attention appears to be directed toward an observation so that she can make a judgment, as Judge A seems to read it by invoking "II-f." This difficulty seems to be a compounding of weighting and of which portions of discourse are to be analyzed.

Episode 11 (p. A22, L. 7-p. A23, L. 8).--Here, it appears that disagreement occurred because judges analyzed different portions of the discourse. Judge A, in the initial part of the episode, focuses on a number of pupil-teacher interactions, while Judge C analyzes one or two passages from among the piece examined by Judge A. There are more significant problems here, though. First, when considering the giving of reasons for the acceptability of a pupil's response (Item II-d), it seems reasonable that this should include the practice of having a youngster think about the limitations of his own response, for the potential consequence is Intellectual Independence. Judge A seems to have recognized the potential consequence of this practice, since LL. 8-36 are characterized by Item II-d. Judge C has not apparently used such an interpretation of Item II-d. Instead, L. 14 is characterized as ID-e.

This clearly calls for amplification of these two items in the scheme, and thus constitutes a practical limitation.

The second problem is one of considering if statements of pupils constitute part of the teaching. Judge B uses a statement by Cathy on LL. 22-25 to indicate that the teaching is providing evidence. Strictly speaking, the teaching is not providing the evidence, although the teacher is allowing evidence to be presented by pupils. Instructions for using the scheme might clarify this matter if they made it plain that the contributions of pupils can be considered as part of the provisions of the teaching.

The final point of disagreement in this episode is among classifications of p. A23, LL. 1-8. Usefully, Judge A indicates his uncertainty in using Item II-d here, and that points to the need for adding the adjective "substantive" to the wording of the item.

Episode 12 (p. A23, L. 8-p. A24, L. 46).--Part of the disagreement here might be accounted for by the lack of specification of what is to count as "procedural" matters, and therefore not subject to analysis. Here, Judge A analyzes the account of the experiment on p. A23, LL. 28-52 and p. A24, LL. 40-46 as providing phenomena about which pupils can make judgments so far as the explanation is concerned. Judge C recognizes that evidence is being provided, but indicates that it is not clear from the discourse which claim is being supported by this evidence. This judgment appears to be substantiated by Judge B's indications that the arguments are absent. Interestingly, Judge A notes the assumption that the teacher is talking about the diffusion of molecules. It could be

that neither Judge B nor Judge C is prepared to make this assumption, thus explaining their apparent disagreement with Judge A's analysis. Indeed, Judge C notes in his analysis of p. A25, LL. 30-35 that there may be some confusion about what is moving: the whole mass (presumably by convection), or molecules (an axiom of the kinetic molecular theory). Since Judge A rests his judgment upon an assumption, it is unlikely that the scheme itself is responsible for the resulting disagreement.

<u>Episode 13 (p. A24, L. 46-p. A26, L. 25)</u>.--Here, Judge C appears to attach greater weight to the presence of two "II" items than appears to be justified. Since Judges A and B are substantially in agreement, and show the presence of more items corresponding to "ID" than does Judge C, it is reasonable to infer that the latter has overemphasized the importance of the treatment given to Anne-Marie's response on p. A26, LL. 5-6, though Judge C notes that the treatment rests upon a contradictory portion of the argument. This overemphasis might be a consequence of the problem of weighting referred to in discussions of previous episodes above, since a similar problem appears in Judge C's analysis of p. A25, LL. 30-35. These lines are characterized as ID-g <u>and</u> II-f. The instructions do not indicate how one is to determine the overall provision of portions of discourse which correspond to items from alternative "sides" of a category.

<u>Episode 14 (p. A26, L. 25-p. A27, L. 16)</u>.--The rather holistic focus in Judge B's analysis of this episode tends to preclude exploration into possible sources of disagreement. Judges A and C agree for approximately the same reasons, apparently, and Judge B acknowledges the

presence of "II-e," but tends to reject the notion that evidence is provided by the teaching when mention is made of the experiment just performed. Beyond this, defensible claims about possible sources of disagreement cannot be made.

Episode 17 (p. A29, L. 14-p. A31, L. 5).--The disagreement here is clearly a matter of uncertainty about what constitutes "procedural" matters. The attributes of procedural matters are unclear, although homework assignments are specifically mentioned in the instructions. Again, then, it seems that the accuracy of the scheme is limited by rather ambiguous instructions.

Implications of Practical Limitations.--All the above problems suggest that minor modifications to the scheme and to the instructions could reduce the small number of disagreements obtained in the reliability estimate. These modifications are beyond the scope of this study.

Implications of the Study

Implications of the study concern the potential of the analytical scheme as either a research device or an instructional device. Implications for research are derived from considering the problem addressed by this study. Implications in the area of instruction come from considering the potential of the scheme in supervising science teaching.

Implications for Research

The problem for this study arose from examining the current state of research on teaching. In Chapter II, the investigator demonstrated

that neither of the two paradigms of research on teaching, the "observation paradigm" or the "achievement paradigm," has generated conceptual devices suitable for investigating consequences of teaching whose significance to pupils has been established in this study. Now that the investigator has generated such a device in the "observation paradigm," three major kinds of implication follow for further research.

First, further work within the "observation paradigm" itself might examine the consistency of a given teacher's style in providing a Realist or Instrumentalist view of science. Perhaps this would vary with the subject matter being taught, but again perhaps it would not. The investigator suspects it is more likely that a given teacher puts an interpretation on all science which is primarily Realist or Instrumentalist. This suggests research into the factors influencing a teacher's development of a view of science, and his own Intellectual Independence or Dependence. One might, for instance, use the scheme to analyze the science teaching to which a group of future teachers is exposed, in a longitudinal study which subsequently looks at the teaching style predominately used by each individual in practice teaching. Studies of this type might produce important information about science teacher-education programs.

Second, an interesting question arises (still within the "observation paradigm") about the finding, within this study, that lessons characterized as providing predominately a Realist view of science were also characterized as providing predominately for Intellectual Dependence, while lessons characterized as providing predominately an Instrumentalist

view of science were also characterized as providing predominately for Intellectual Independence. This finding invites investigation. Further analysis of the reliability of the scheme itself would be in order, given the limitations discussed earlier. Then a study of a large number of analyzed lessons, to examine the association of paired characterizations of R/ID and I/II, would be most revealing. (The investigator suspects that the association would be rather high, as it seems intuitively to be in the two lessons of the present study.)

Third, the theoretical basis developed for this scheme provides the conceptual network needed to generate measuring devices to detect actual consequences of teaching characterized as providing for Realist or Instrumentalist view of science, and for Intellectual Independence or Intellectual Dependence. If such measuring devices were developed, correlational studies within the "achievement paradigm" could be mounted to examine the actual consequences of science teaching on these fundamentally important dimensions. The evidence about teaching, garnered from the scheme, would be correlated with evidence about consequences for pupils, garnered from the measuring devices. This correlational evidence is of such a nature that it would permit relatively strong inferences to be made about features of science teaching and consequences for pupils.

Implications for Supervision of Science Teaching

Any device which enables one to document the potential consequences of classroom discourse is useful *prima facie* for the supervision of teaching. By using any analytical scheme, a supervisor can support

claims he makes about the potential of a lesson with evidence derived from analyzing it with the scheme. The novice teacher is thus provided with specific reasons for a supervisor's judgments, and can become less dependent intellectually upon the supervisor for such judgments.

The implications for supervision of science teaching which follow from this study are two. First, the substance of the scheme permits a supervisor to make an issue of the differences between Realism and Instrumentalism, and between Intellectual Independence and Intellectual Dependence. This area of science teaching, hitherto unexamined, is of fundamental importance to pupils. Second, the use of the scheme permits the supervisor to instruct the novice that there are indeed alternative views of science, and that lessons can make fundamentally different provisions for one or the other. The same is true for Intellectual Independence and Intellectual Dependence.

Summary

This concluding chapter has reviewed both problems and purposes of this study, and the steps taken to address them. Conceptualizations from the philosophy of science, theory of knowledge, and philosophical analysis of teaching have been used to derive a scheme for analyzing science teaching. This scheme allows one to identify specific intellectual consequences of classroom discourse: the view of science provided (Realism or Instrumentalism) and the provision for Intellectual Independence or Intellectual Dependence. The investigator has shown these consequences to be fundamentally important for pupils.

This analytical scheme was revised following a trial analysis,

and was then submitted to a trial by three independant judges to estimate its reliability. An analysis of the resulting agreements showed the overall percentage of agreement to be 82.3 per cent. The estimate is that reliability between pairs of judges is statistically significant at the .01 level of confidence. It was found that minor changes to the scheme and to the instructions might reduce the number of disagreements obtained in the reliability trial.

The study concluded that the analytical scheme developed here has potential for further research on science teaching, and for the practice of supervising science teaching.

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APPENDIX

INITIAL ANALYTICAL SCHEME

Category 1: View Of Science Provided For

R - REALIST:

a. Theoretical statements have the same logical form as observation statements.

b. "Scientific objects" have the same ontological status as common-sense objects of perception.

c. Science is presented as the only acceptable way of describing or explaining the world.

d. Science is spoken of as superior to alternative explanatory modes.

e. Past theories presented as false.

f. Lapsed "scientific objects" given as inaccurate accounts of reality.

g. The potential of science for explaining or describing the world is given as unlimited.

h. The use of a model, law, theory, or convention is not signalled.

i. A model, law, theory, or convention is invoked as a description of phenomena.

I - INSTRUMENTALIST:

a. Theoretical and explanatory statements have a different logical form from observation statements.

b. "Scientific objects" have a different ontological status from common-sense objects of perception.

c. Science is presented as one way of explaining phenomena.

d. Science is spoken of as in competition with alternative explanatory modes.

e. Past theories are presented as inadequate.

f. Lapsed "scientific objects" are given as inadequate explanatory devices.

g. The potential of science for explaining and describing is given as limited.

h. The use of a model, law, theory, or convention is signalled.

i. A model, law, theory, or convention is invoked as an explanation of phenomena.

INITIAL ANALYTICAL SCHEME (continued)

Category 2: Provision For Intellectual Independence Or Dependence

II - INTELLECTUAL INDEPENDENCE:

a. Evidence is provided in support of claims.

b. The strategy of truth determination is present.

c. The argument is present.

d. The correspondence of diagrams or models to phenomena is demonstrated by evidence and argument.

e. Reasons are given for the acceptability of a pupil's statement or response.

f. The questions and objections of pupils are honored and are treated with regard to reason.

g. Pupils have provision to make judgments of the viability of models and theories by recourse to phenomena.

h. Alternative models and theories are provided to permit pupils to make judgments among them.

ID - INTELLECTUAL DEPENDENCE:

a. Evidence is not provided in support of claims.

b. The strategy of truth determination is not evident.

c. The argument is absent.

d. The correspondence of diagrams or models to phenomena is not demonstrated by evidence nor by argument.

e. Reasons for the acceptability of a pupil's response are absent.

f. The questions and objections of pupils are not honored and are not treated with regard to reason.

g. Provision is not made for pupils to make judgments of the viability of models and theories by recourse to phenomena.

h. The making of judgments among alternative models and theories is preempted since alternatives are not provided.

REVISED ANALYTICAL SCHEME

Category 1: View Of Science Provided For

R - REALIST:

a. Theories are stated as if they have the same logical status as observation statements.

b. "Scientific objects" (postulated entities) are talked about as if they have the same ontological status as common-sense objects of perception. They have a physical reality.

c. Science presented as the only acceptable way of describing or explaining the world or phenomena.

d. Science spoken of as superior to alternative explanatory modes.

e. Past theories are presented as false.

f. Lapsed "scientific objects" given as inaccurate accounts of reality.

g. The potential of science for explaining or describing is given as unlimited.

h. That a model, law, theory, or convention is being used is not signalled to pupils.

i. A model, law, theory, or convention is invoked as a description of phenomena.

I - INSTRUMENTALIST:

a. Theoretical and explanatory statements are stated as if they have a logical status different from that of observation statements.

b. "Scientific objects" presented as having a different ontological status from common-sense objects of perception. They are postulated entities.

c. Science presented as one way of explaining the world or phenomena.

d. Science spoken of as in competition with alternative explanatory modes.

e. Past theories presented as inadequate.

f. Lapsed "scientific objects" given as inadequate explanatory devices.

g. The potential of science for explaining and describing is given as limited.

h. That a model, law, theory, or convention is being used is signalled to pupils.

i. A model, law, theory, or convention is invoked as an explanation of phenomena.

REVISED ANALYTICAL SCHEME (continued)

Category 2: Provision For Intellectual Independence Or Dependence

II - INTELLECTUAL INDEPENDENCE:

a. Evidence is provided in support of claims.

b. The argument is present.

c. Correspondence of diagram or model to phenomena is demonstrated by argument and evidence.

d. Adequate reasons given for the acceptability or unacceptability of a pupil's statement or response.

e. Suggestions, questions, and objections of pupils are honored and are treated with regard to reason.

f. Pupils have provision to make judgments of the viability of models, theories, and explanations by recourse to phenomena.

g. Alternative models, theories, and explanations are provided to permit pupils to make judgments among them.

h. Discrepancies among observations or evidence are rationally resolved.

ID - INTELLECTUAL DEPENDENCE:

a. Evidence is not provided in support of claims.

b. The argument is absent.

c. Correspondence of diagram or model to phenomena is not demonstrated by evidence or by argument.

d. Adequate reasons for the acceptability or unacceptability of a pupil's response are absent.

e. Suggestions, questions, and objections of pupils are not honored or are not treated with regard to reason.

f. Provision is not made for pupils to make judgments of the viability of models, theories, and explanations by recourse to phenomena.

g. The making of judgments among alternative models, theories, and explanations is preempted since alternatives are not provided.

h. Discrepancies among observations or evidence are not resolved on rational grounds.

INTRODUCTION TO THE STUDY

The purpose of this study is to construct an analytical scheme which may be used for detecting potential consequences of science teaching. This method of analyzing teaching, it is argued, is a viable alternative to methods for determining consequences of teaching by examining, in various ways, the sorts of things learned by pupils. Thus the scheme might be particularly valuable in the area of supervision since it provides a systematic framework for detecting the potential of ongoing teaching.

The scheme consists of a set of items designed to correspond to features of any teaching dialogue which can then be identified as making provision for specific intellectual consequences. The intellectual consequences chosen for this study fall into two main categories, "View of Science" and "Intellectual Independence or Dependence," as described below.

"View of Science" Category

It is argued in the body of the study that a major and inevitable portion of the potential of science teaching is its capacity to depict or reflect a particular view of science (and indeed, of the world). For present purposes, two major views of science have been chosen which have potential for logically implying quite distinct intellectual consequences. The terms "Realist" and "Instrumentalist," which respectively connote these views, are taken from Nagel's Structure of Science: Problems in the Logic of Scientific Explanation. It is shown in developing the scheme that each view is to be associated with distinct views about the ontological status of constructs (called here "scientific objects" after Nagel's terminology), the logical status of theories, and about the explanatory power of science as an explanatory device. The distinctions between each view of science constitute the items listed in the first category of the analytical scheme.

"Intellectual Independence and Dependence" Category

Since science and science teaching typically embody knowledge claims, it is to be expected that science teaching has considerable potential for influencing and governing the manner in which pupils come to know or to believe the truth of assertions about phenomena. In the theoretical portion of the study, writings in epistemology and the philosophical analysis of teaching have been used to develop the constructs "Intellectual Independence" and "Intellectual Dependence" as potential intellectual consequences of science teaching (or any teaching, for that matter), and these constructs form the items in the second category of the analytical scheme.

Briefly, teaching that provides for Intellectual Dependence is construed as teaching that leaves youngsters dependent intellectually upon the teacher. Such teaching would deny the youngsters the opportunity

for judging the truth of a claim, for instance, by failing to provide evidence or argument that support the claim. Similarly, judgments about the adequacy of theories or explanations might be preempted by teaching if that teaching does not show the phenomena that explanations or theories are designed to handle; judgments among competing explanations might be preempted in similar fashion. All such instances leave the youngster dependent upon the teacher for assessing or judging the adequacy of the theory or explanation. Alternatively, teaching that provides for Intellectual Independence would provide, for example, argument, alternative theories and explanations, and the like, so that judgments about truth and adequacy may be made by the youngster independent of the teacher. The epistemological roots of these alternatives may be clearly seen in the items of Category 2.

Further items reflecting the Intellectual Independence and Dependence category have to do with the manner in which assertions and questions of pupils are treated during the lessons analyzed. Such items have to do with respecting the pupils' prerogatives in various ways. In the theoretical portion of the study, it is argued that respecting prerogatives about ways in which pupils make claims and honoring statements and questions are prerequisite to providing for Intellectual Independence.

Usefulness of the Scheme

Items in the two categories of the scheme are designed so that statements or series of statements in portions of teaching may be identified as corresponding to one or more of the items. In this way, it is possible to infer the intellectual consequences provided for by the teaching. This sort of "on-the-spot" analysis of teaching suffers because of its dependence upon how youngsters might understand things said in the observed lesson. For instance, a teacher might be presenting a single explanation for a phenomenon, and the substance of the lesson might not indicate whether or not alternative explanations had been discussed in a previous unobserved lesson. Thus, the context in which lessons are given is most important. In an effort to determine the context of observed and recorded lessons, the writer recorded an interview with the teacher following the lesson. The questions asked in this interview attempt to have the teacher speak of context, while at the same time attempting to keep the questions as open and threat-free as possible.

Together the scheme and the interview provide one with a device for determining some intellectual consequences of science teaching. Yet, it is necessary to show that the scheme can be used by independent persons in such manner that similar judgments about the potential consequences result. In this way, the reliability of the scheme can be assessed. Independent judges are requested to use the scheme in the manner indicated to make judgments about a science lesson, using transcriptions of the lesson and of the accompanying interview.

Testing the Scheme

The investigator will determine the reliability of the analytical scheme by comparing judgments of independent judges with his own judgments. If the scheme is found unreliable, it will be revised and another test for reliability will be performed. In such an event, the same independent judges will be asked to use the revised scheme to analyze a different science lesson.

INSTRUCTIONS FOR USING THE ANALYTICAL SCHEME

1. Independent judges are requested to perform the analysis without consulting anyone who may or may not be familiar with the study.

2. It is recommended that the analysis be written on the working copy of the lesson in pencil. When complete, the analysis is to be copied on to the good copy. Typing is not necessary. Both the good copy and the analytical scheme are to be returned to the investigator in the envelope provided. If it is wished, independent judges may include in the envelope notes or comments concerning difficulties encountered during the analysis, such as problems of clarity, use of notations, and the like.

3. Before analysis, it is recommended that the lesson and interview be read in their entirety so that they become quite familiar.

4. The lesson has been divided into several "Episodes" which are identified on the transcript. For each episode, two judgments are to be made: first, that the episode provides for a Realist or Instrumentalist view of science; second, that the episode provides for Intellectual Independence or Intellectual Dependence.

   It is to be emphasized that two judgments must be made for each episode. (The reliability of the scheme is determined from the amount of agreement among judgments of independent judges; so judgments must be made whatever the quality or quantity of support for such judgments.)

5. Even though the judgments are to be made about individual episodes and even though most data supporting judgments will be found in the episode being judged, additional data from any part of the lesson or interview may be used.

6. Sometimes, portions of lessons are devoted to procedural matters, such as making homework assignments, instructing in the use of equipment, and the like. Such matters are not amenable to judgment according to the scheme. Thus, if whole episodes are devoted to these matters, they need not be judged. Instead, they should be marked "Procedural only." The scheme is only to be used for analyzing those portions of teaching having to do with substantive claims about states of affairs and with the manner in which such claims are handled in the teaching.

7. The analysis is to be written in the right-hand space opposite the transcribed dialogue.

8. The following notation is to be used for page and line references: L. for line, LL. for lines, p. for page.

   When referring to pages of the lesson other than that on which the

analysis is being written, it is sufficient to use p. followed by the appropriate page number.

When referring to pages of the interview, write the word "interview" before p. and the page number.

Page number references need only be given when referring to lines on pages other than that being analyzed. For example, if a portion of teaching on page five between lines 16 and 21 is being analyzed, then the notation, LL.16-21 is adequate identification. If the portion being analyzed extends to a new page, and the analysis is written on the first page, then the legend, L.38-p.6, L.3 is sufficient, for example.

9. The following code is to be used for indicating particular items of the scheme that correspond to portions of the teaching:

   I-a, I-b, I-c, etc, for items of the scheme appearing beneath "Instrumentalist."

   R-a, R-b, R-c, etc. for items of the scheme appearing beneath "Realist."

   II-a, II-b, II-c, etc. for items of the scheme appearing under "Intellectual Independence."

   ID-a, ID-b, ID-c, etc. for items of the scheme appearing under "Intellectual Dependence."

10. Each episode is to be analyzed as follows:

    a. Identify words or statements within the episode, or portions of the episode, which correspond to one or more items of the scheme. Write beside that word, statement, or portion its line reference <u>and</u> the item(s) it corresponds to in the scheme, as shown in the following example.

       (This example is fictitious and does not necessarily refer to any portion of the lesson to be analyzed.)

       If a portion of teaching between lines 18 and 20 corresponds to items I-b and ID-c of the scheme, then write beside this portion:

       LL.18-20: I-b; ID-c.

       If this correspondence is supported (or refuted) by a further portion of the lesson, or by a portion of the interview, then indicate as much giving page and line references.

    b. Continue identifying correspondences of words, statements, and portions of the episode with items of the scheme until you are satisfied that all such correspondences have been identified.

c. On the basis of the data obtained from these correspondences, judge if the episode as a whole provides for a Realist or Instrumentalist view of science, and if the episode provides for Intellectual Independence or Intellectual Dependence.

d. Report this judgment by writing one of the following beneath the heading of the episode just analyzed:

R/ID, R/II, I/ID, I/II.

Thus, if an episode is judged as providing for Intellectual Independence and for a Realist view of science, this judgment would be reported as: R/II.

Note that each and every word, statement or portion of the episode will not be amenable to identification with an item of the scheme. Also, some statements or portions may be found to correspond with more than one item of the scheme. (In the latter case, it is important that all such correspondences be noted.)

11. When the analysis of one episode is complete, the next episode is to be analyzed and so on until the whole lesson is analyzed.

12. When the whole lesson has been analyzed, all judgments should be carefully checked; then the analysis is to be copied on to the "good" copy of the lesson. The "good" copy and the analytical scheme are to be returned to the investigator in the envelope provided.

TRANSCRIBED SCIENCE LESSON:

"THE MOVEMENT OF ATOMS AND MOLECULES"

(The lesson begins.)

Teacher: All right. Chris, what are...what makes up all matter?

Chris: Ah...atoms.

Teacher: Right. If you combine two or more atoms, what is the particle that's formed? Kevin.

Kevin: Molecule?

Teacher: All right. If, er, we think of matter as being composed of molecules--here I have an onion that someone in biology is growing. If I break up the onion--cut it open at the front, eventually you would be able to tell that I cut it open other than just seeing me do it. How would you know? Maurice.

Maurice: The smell?

Teacher: All right. So we get the odor at the back. What possible ways would there be for the odor to travel from the front to the back? What explanation could you give? Alan.

Alan: Well, you could say that it was wind currents. But it isn't.

Teacher: Okay. (Some laughter) Bill.

Bill: Er, all gases, er... they all spread out until they're equal. And so, er,

EPISODE 1 (L.1 - p.A13, L.10)

Judge A: R/ID

LL.1-5: ID-a, b, d; R-b, h.
LL.5-10: ID-a, b, d; R-b, h.
LL.10-12: ID-a; I-a.
LL.15-16: II-f (assuming the onion is opened).
L.28: I-i
LL.28-33: ID-d; R-h ("current" involves a model too).
L.35-p.A13, L.5: ID-d; R-h, i.
p.A13, LL.5-10: ID-c, d, f, g ("air current" model not considered as an alternative).

Judge B: R/ID

LL.1-12: R-b, h, g.
L.5 and L.10: ID-d.
LL.10-21: ID-c.
L.25-p.A13, L.4: ID-c.
L.25-p.A13, L.9: I-i.
LL.35-37: ID-a.
L.35-p.A13, L.9: R-h, a.
p.A13, LL.5-10: II-g; ID-d,a.

Judge C: R/ID

L.4 and L.9: R-b (Interview, p.A33, L.37; p.A34, L.42-p.A35, L.19, especially L.19).
LL.10-13: I-b (this in contradiction to the above references to interview).
L.25: ID-d.
LL.23-24: ID-a.
L.33: ID-d, f ("currents" appear later, p.A25, LL.33-43. There the two alternative explanations are treated as the same).
p.A13, L.5: ID-d, f.
p.A13, L.10: ID-d, f.

the gas would come back to the back of the room and spread around the room until the odor is equal all around.

Teacher: All right. Would we have to have air currents in the room or would it happen without them? Pete.

Pete: No.

Teacher: All right. Now, when we have a certain amount of substance we talk about concentrations. What sort of concentration would there be around this onion as soon as I cut it open? What kind of onion would you, er, onion odor concentration? Angie.

Angie: High concentration.

Teacher: Right. How would we compare the concentration at the back of the room? Chris?

Chris: Low.

Teacher: Right. What direction would we have the movement of gas? Yes.

Pupil: From high to low.

Teacher: All right. So we've got it moving back throughout the room. We had the same thing happening with ammonium hydroxide--if you remember. We could smell the ammonia smell throughout the room, it started at the front and moved back. When would the movement essentially slow down and perhaps stop? Yes.

Pupil: When it was pretty well equal around the room?

EPISODE 2 (L.10 - L.38)

<u>Judge A:</u> R/ID

LL.10-13: ID-c; I-a ("we talk about" read as "we talk as though there were").
LL.17-21: ID-c, d; R-h.
LL.21-26: ID-c, d; R-h.
LL.26-30: ID-c, d; R-h.
LL.32-33: II-f

<u>Judge B:</u> R/ID
LL.10-13: R-h.
LL.10-38: R-i.
L.21: ID-d.
LL.26-28: ID-c.
LL.32-38: II-a.

<u>Judge C:</u> I/ID

LL.10-13: I-h.
L.21: ID-d.
L.26: ID-d.
LL.32-36: II-b (by analogy, thus the reasoning may be considered as present).

EPISODE 3 (L.38 - p.A14, L.36)

<u>Judge A:</u> R/ID

LL.38-41: ID-c; R-a, b, h, i (assuming that "molecules" are what slow down--from p.A12, LL.10-12, one

Teacher: All right. So, er the motion would eventually come...at least, slow down and come to a halt. There's a name given to this particular process whereby things move from a high concentration to a low concentration. What do we call it? Debrah.

Debrah: May I leave the room, please?

Teacher: Yes. (Debrah leaves) Let's try again. Heather.

Heather: Diffusion?

Teacher: Right. So diffusion's occurring. In this case we're talking about diffusion in gases--one gas diffusing through another. Now, it would take a certain length of time for the gas to pass from the front of the room to the back. But, after a certain length of time we get the onion smell throughout the room and probably the people in the hall would turn up their noses as they walked by because of this onion smell as well. So, it diffuses throughout the room, and this is called "diffusion". Now diffusion is affected by certain things--the movement of molecules is affected by certain things. What does an object have to possess to be able to carry on movement within itself, without having an external agent move it? Yes.

Pupil: Energy?

Teacher: Right. What types of energy are there...some examples? Brian.

can infer that the teacher is talking about molecules, or at least particles).
p.A13, L.38-L.1: ID-d.
LL.1-4: R-b (again, assuming molecules are the referents for "things" --see p.A13, LL.36-40).
LL.4-9: I-h--what something is called is a convention. But R-h because the model (concentration) is not presented.
LL.4-18: ID-g.
LL.17-22: R-h.
LL.18-36: ID-c, g; R-h.

<u>Judge B:</u> R/ID

p.A13, L.38-L.36: R-h, i.
LL.4-9: R-a.
L.17: ID-d.
LL.18-36: ID-g.

<u>Judge C:</u> I/II

LL.1-5: this "movement of molecules" is alleged to stop here. On p.A15, LL.39-46, it is asserted that all molecules move.
L.1: ID-d.
LL.1-4: ID-a (that pupils have detected this is not evident).
LL.4-9: I-h.
LL.22-26: II-a (although the evidence is not presented here, it is clear that pupils have experienced this time lapse in a previous lesson, as stated by the teacher on p.A15, LL.18-35).

EPISODE 4 (L.36 - p.A15, L.18)

<u>Judge A:</u> R/ID

LL.38-44: ID-g; R-h (but, see later experiments, pp.A23-A24).
LL.38-47: ID-a, b, c, d (later, pp.A21-A25, they do an experiment with heat).
p.A15, LL.6-14: ID-c, d, g.
p.A15, LL.16-18: ID-a, c, f; R-b, h (but, p.A21, LL.43-p.A25 indicates II-a, f).

Brian: Heat, light,...I forget the other one.

Teacher: Another one that we mentioned? Stephanie.

Stephanie: Sound.

Teacher: All right. Which of those three--they're three of the main ones that we've been talking about lately. Which one of those three do you suppose acts on molecules? Pete.

Pete: Heat?

Teacher: Okay. So, heat affects energy...excuse me. Heat affects movement of molecules in some way or other. Now we've done a number of demonstration experiments to show diffusion --movement from a high concentration to a low concentration. We have done it with ammonium hydroxide in the air, ammonium hydroxide in hydrochloric acid in the long tube and we had them both moving. We had ammonium hydroxide and hydrochloric acid in those two gas jars. Also we had a solid dissolving and moving throughout a liquid--the potassium permanganate and water. From those four types of experiment what things have we learned from, about molecules? What do we know about...some of the things that we know? Heather.

Heather: They move?

Teacher: All right. First point...we just were talking about that so that's number one. (She writes on the

<u>Judge B:</u> R/ID

p.A14, LL.36-44: R-a, b, i.
p.A14, LL.36-47: ID-g.
p.A14, LL.40-49: R-h.
p.A13, L.47: ID-d.
LL.10-18: R-b.
L.14: ID-d.
LL.14-18: ID-a.

<u>Judge C:</u> R/ID

p.A14, LL.36-40: ID-a.
p.A14, L.47: ID-d.
p.A13, L.48: R-b (Interview p.A33, L.21).
The allegation that these are types of energy, <u>describing</u> phenomena of heat, light, and sound is R-i. (p.A21, LL.31-35 supports that this is asserted--determining the direction of effect is the purpose of the experiment.)
L.14: ID-d.
LL.16-18: ID-a.

EPISODE 5 (L.18 - p.A16, L.13)

<u>Judge A:</u> R/ID

LL.18-35: II-f.
LL.36-43: ID-d, g; R-b, h.
p.A16, LL.1-3: R-b, h ("of molecules" is added later--p.A29, LL.34-37).
p.A16, LL.2-5: ID-d; R-b, h ("of molecules" added).
p.A16, LL.10-13: ID-a, b, c, d, g; R-b (but see pp.A23-A24).

<u>Judge B:</u> R/ID

L.36-p.A16, L.12: R-b; ID-c.
p.A16: ID-b, a.
p.A16, L.5: ID-d.
p.A16, LL.6-8: R-h; ID-g.
p.A16, LL.10-13: ID-b.

<u>Judge C:</u> R/ID

LL.18-35: Here evidence for a number of previous claims is referred to. (Note that the manner in which "molecules" is understood parallels

board "1. movement".) Something else that we know about molecules? Yes.

Pupil: They move by heat.

Teacher: Yes, okay...What do, what is heat? It's not a type of matter but what is it? Cathy.

Cathy: Energy?

Teacher (Writing on the board "2. energy in the form of heat causes movement"): ...thinking of something else that we know. (Pause) Think of anything else? Think about the experiment with the long tube that we had. Now we had two liquids that turned into gases--they evaporated. Movement from one gas came from one end, the other gas came from the other end. Did they move at the same rate? John.

John: No. The, um, one went faster than the other one.

Teacher: How did we know that one had to go faster than the other? They were clear, colorless gases--we couldn't see them. Brian.

Brian: Because a cloud of gas formed over one side of the tube and not in the middle.

Teacher: All right. I... someone remember which gas moves most quickly? Brian.

Brian: Ammonium?

Teacher: Okay. Ammonia gas ...ammonium hydroxide. So

previous mentions of the word, p.A12, LL.9 and 12.) So, p.A15, L.39: R-b (reference to Interview in Episode 1). Because no additional reasoning supplied since this assertion last made ("molecules move" p.A14, LL.37-38) the provisions are the same.
p.A15, L.34: ID-d. Note also that "movement" ceases (p.A13, L.47 and p.A14, L.4). No means for judging appropriateness of either assertion: ID-f.
L.4: ID-a (appears to be a recall of p.A15, LL.16-18).
L.5: ID-d.
L.9: R-b.
LL.11-13: ID-a.

EPISODE 6 (L.13 - p.A17, L.17)

Judge A: R/II

LL.13-23: II-f (report of experiment).
LL.31-33: I-b (given the perception--sight--the gas is not detectable, although it is probably not considered as a postulated entity).
LL.24-38: II-d.
LL.39-42: ID-d (because there is no link made between ammonia gas and position of cloud).
p.A17, LL.3-9: R-b, h (provision was not apparently made for pupils to see that they're talking about models--Interview pp.A34-A35).
p.A17, LL.9-13: II-f.
p.A17, LL.9-17: R-b, h.

Judge B: R/ID

LL.18-20: ID-a, b.
LL.18-37: R-h, i.
LL.34-37: II-a.
p.A17, LL.3-8: ID-b, c.
p.A17, LL.3-16: R-b, h, i; ID-g.
p.A17, L.9: ID-d.

Judge C: R/II

(Here, reasoning behind John's claim, LL.26-28, is extracted.)
LL.34-37: II-a (how this assertion fits the argument is not made clear; yet, if pupils have seen elsewhere

that the cloud that was formed when those two gases met, formed at one end. So what do we know about molecules that compose gases? Are they all the same? Shirley.

Shirley: They're different.

Teacher: All right. What do we, what characteristics do we know must be different about those molecules from that experiment? What characteristic? Anne-Marie.

Anne-Marie: Some travel faster than others?

Teacher: Okay, one thing. Now the one that travels faster, since it did travel faster, what do you suppose the, er, density of that gas would be? Ron.

Ron: Lighter?

Teacher: Than what?

Ron: Than, than the other one would?

Teacher: All right. Lighter than the other one because it did travel faster. So that we had, in both cases, the same amount of heat at both ends; so that one must have been lighter than the other. So we learned that molecules of gases travel at different speeds, and they also--let's get this onion out of the way--they travel at different speeds, and they also, er, are of different weights. (She writes on the board, "3. molecules vary in weight therefore travel at different speeds".) If we think of

that the product of mixture of gases is a cloud, then the argument is present. This is evident from the Interview, p.A32, LL.20-22). II-b.
LL.1-3: II-b.
LL.3-6: R-b, i.
Anne-Marie's statement, LL.15-16, follows if gases <u>are</u> made of molecules. This has been asserted previously, thus reasons for the correctness of this statement are present: II-d.

EPISODE 7 (L.18 - L.45)

<u>Judge A:</u> R/ID

LL.18-20: R-b.
LL.18-29: ID-d (reason is inadequate).
LL.27-29: ID-b, c, g.
LL.29-45: II-b (argument present, although inadequate).
LL.38-39: II-f (from the experiment).
LL.40-41: ID-a, b, c.

<u>Judge B:</u> R/ID

LL.18-27: ID-b, d.
LL.29-34: ID-a.
LL.32-34: ID-b.
LL.34-44: R-b.
LL.40-41: ID-a, b.

<u>Judge C:</u> R/ID

LL.32-34: ID-g (judgment preempted because "heat" has only been asserted as a "cause", no other explanations are considered. Interview p.A36, LL.12-22 indicates previous work with density and relation to mass and volume. No mention of volume in lesson. Interview p.A35, L.33-p.A36, L.9 does not refer to these substances), ID-b.
LL.43-45: ID-b (no argument to move speed to weight).
L.35: R-b.

the experiment with the ammonia gas--the ammonium hydroxide moving throughout the room--and you think of the experiment with potassium permanganate in the water, which experiment happened more quickly... which, in which case did the diffusion, rather, occur more quickly? Alan.

Alan: In, um...when you added...can you say that again, please?

Teacher: Okay. Ammonium hydroxide in air or potassium permanganate in water.

Alan: It was the ammonia in air?

Teacher: Okay. Now, it happened in this...in this particular case it happened more quickly. Does it seem reasonable to assume that diffusion happens more rapidly in gases than in liquids? Does it seem reasonable? Shirley.

Shirley: I think it does.

Teacher: Right. Someone give an idea why does it seem moı reasonable? Yes.

Shirley: Because, er, gas is less dense, the air is less dense and it can move more quickly because they don't have so much to push through.

Teacher: All right. The idea about pushing through ...now think when you walk through the air, you don't really notice any...anything holding...holding you back.

EPISODE 8 (p.A17, L.45 - p.A19, L.34)

Judge A: R/ID

LL.1-11: II-f.
p.A17, L.45-L.21: ID-d.
LL.25-28: ID -g; R-h.
LL.25-40: ID-d (although teacher has, through equations, given the reason for the acceptability of the pupil's response, I judge the reason as inadequate on the grounds that it depends on a model which has not been made explicit).
LL.34-40: R-h.
p.A19, LL.15-21: R-b.
p.A19, LL.1-21: R-h (it is evident that a model is being assumed in order to make the argument).
p.A19, LL.15-21: ID-g.
p.A19, LL.15-25: R-b, h.
p.A19, LL.1-34: II-b, d (although the argument is weak--p.A19, LL.1-13).

Judge B: R/ID

LL.9-11: R-a.
LL.25-28: R-h, i.
L.31: ID-d.
L.40-p.A19, L.21: ID-g.
p.A19, LL.16-33: R-b; ID-c.
p.A19, LL.22-34: ID-a, b, d.

Judge C: R/ID

LL.2-7: II-a (two previous experiments have been experienced).
L.31: II-d.
LL. 34-39: R-b (presumably, "it" refers to the gas and "they" to the molecules).
p.A19, LL.3-14: R-i; ID-g (noting the single explanation for these phenomena).
p.A19, L.18: R-b.
p.A19, LL.22-24: R-b.
In p.A19, LL.22-33, the complete argument is absent. Nothing is said of spaces in between molecules that might be different from freedom of molecules to move around: ID-b, d.

You don't have to fight your way through the air. If you are swimming in water, you find that there is a little bit of er... opposition, if you like, as you go through the water you have to put a bit more energy to it to get through it. Then if you try to go through a solid, you can't. It's there and you can't pass through it. The three different types of substances are much different. If we consider the molecules in air as compared, say, to the molecules in a solid, what about the way they're arranged as far as the spaces in between? Heather.

Heather: Would the air, would the molecules in the air be farther apart?

Teacher: All right. What about the molecules in a liquid?

Heather: Oh, well. They'd be farther apart than in a solid...

Teacher: All right...

Heather: ...between the liquid and solid.

Teacher: All right. How could...what would be a very simple way of showing that the molecules in air have to be further apart than the molecules, say, in this desk? (Pause) You're just sitting there. Ron.

Ron: You can't walk through a desk but you can walk through air.

Teacher: All right. And you can push the air aside

EPISODE 9 (L.34 - p.A21, L.7)

<u>Judge A:</u> R/ID

LL.34-40: ID-g; R-b, h.
LL.34-45: ID-c, g.
p.A20, LL.19-23: ID-a.
p.A20, LL.16-33: R-b, h, i.
p.A20, LL.29-37: ID-d (I would challenge the adequacy of the teacher's reasons for accepting the pupil's response on the grounds that the argument upon which the whole case is based lacks evidence; see above, p.A20, LL.19-23: ID-a,

and go through it. If we put a gas, once again, up at the front we can even show more conclusively, because you could say, for example, "Well, I've got some sheets of paper here, and I can go through those. So, you know, they're not solid, I can go through them." Well, it isn't really the same idea... (returning some papers to a pupil) by the way, that's your exam left from the other day...Um, if we take a gas at the front of the room, it passes through the air. It's very difficult to get it to pass through a solid like this (touching the front desk), it would take a very, very long time. Eventually you could get it passing through a particular type of solid, but it would take a great deal of time to get through. So if we compared the speed of diffusion which state would diffusion occur the most quickly...in which state? In...er through a gas, a liquid, or a solid? Cathy.

Cathy: A gas?

Teacher: Right. And which one would it occur in the most slowly? Heather.

Heather: A solid?

Teacher: Right. So we can figure out another point, that we have different rates of diffusion. And, depending on what state the substance is in...is in, we have different rates of diffusion. (Writing of the board, "4. Rates of diffusion vary:

and LL.24-28: ID-a). Apparently earlier, p.A18, LL.1-11, pupils have observed different rates of diffusion. However, the way that this section reads, it seems that the conclusion that "Rates of diffusion vary" is not based on those observations, but rather is based on the tenuous argument in LL.16-35.

p.A21, LL.3-7: ID-a, b (the argument is weak because it assumes an unstated model).

Judge B: R/ID

p.A19, LL.34-40: R-b.
p.A19, L.34-L.7: R-h, i.
LL.19-28: ID-a, b, c.
L.37: ID-d.
L.41-p.A21, L.7: R-a; ID-b, c, a.

Judge C: R/ID

p.A19, LL.34-40: R-b, c, i.
LL.11-12: ID-b, g.
LL.22-28: ID-a.
L.37: ID-d (although from p.A18, LL.1-20, Cathy has evidence to judge rates of diffusion in gases and liquids, she cannot so judge these when "solid" is added--this being asserted by the teacher, p.A19, LL.22-28).
L.41: ID-d.

gas--rapid, liquid, solid--more slowly".) Rates of diffusion vary. And we have...for gas we have rapid diffusion...and the solid, more slowly...with the liquid in between. Can you think of anything else that we may gather or figure out from the experiments we've done? Those are really the four main points. The first one is the most important, that we did find out that there was movement of molecules first of all. And the rest we found out, sort of incidentally, by doing experiments. Now, um, we said in number two, "energy in the form of heat causes movement" or affects movement--perhaps would be a better word to write in first of all (changing "causes" to "affects" on the board). Now, we don't know for sure...leave your pens down please, you'll have lots of time to get it later. We don't know for sure from the experiments we've done how heat affects movement--whether it increases or decreases movement. Can you think of a way that we could show the effect of heat on the movement of molecules? Is there any way that we could, say, modify some of the experiments that we've done? Some way that we could show the effect of heat? Kim.

Kim: Er, the glass tube that you had up here before ...um, you could do it first of all without heating it just at room temperature and time it for how long, er, it takes for the gases

EPISODE 10 (L.7 - p.A22, L.7)

<u>Judge A:</u> R/ID

LL.12-39: ID-g; R-b, h (see p.A14 and p.A15--there it was <u>just</u> asserted that heats acts on molecules). The above judgment is made because no alternative models are presented and the molecular model is assumed, not explicitly stated.
L.39-p.A22, L.4: ID-e.

<u>Judge B:</u> R/ID

LL.7-12: ID-f, g.
LL.12-16: R-h, a.
LL.35-39: R-h.
LL.35-43: ID-g.

<u>Judge C:</u> R/ID

LL.20-22: ID-b, f (heat effects have not been observed previously--noting the experiments referred to by the teacher in this episode).
L.21: As noted in the analysis of Episode 4 (p.A15, LL.16-18) that heat effects movement is asserted--the purpose of the forthcoming experiment being directed at finding out in which direction the cause acts.
LL.35-39: R-b, i.
p.A22, LL.4-5: ID-e.

to meet. Then do it again and this time heat it, and time that.

Teacher: All right. That would be one possible way. Any other way? That's with that long tube. Any other way we could do it? (Pause) Heather.

Heather: You could do it with that two glass jars too. You would have to try it warmer.

Teacher: All right. What might be a problem with those two glass jars doing it cool--say room temperature's cool--and then heating it up? There'd be one drawback in that case. Cathy.

Cathy: It happened so quickly when it's cool that you wouldn't probably notice much difference.

Teacher: Okay. Agree Heather? Right. That... it just happened very, very quickly when we started--when we did it at room temperature. So to increase the temperature you'd have to have some way of...of seeing even more quickly. So that would be a little bit difficult. Any other way? Any other ideas? (Pause) Now think. We use potassium permanganate could we do it in that, using that experiment? Potassium permanganate in water.

Cathy: I think you could heat up the water in one while...while it's dissolving.

EPISODE 11 (L.7 - p.A23, L.8)

Judge A: R/II

I judge Episode 11 as Realist even though there are no statements within the episode that speak directly to Category 1. The justification for this judgment lies in the fact that the entirety of Episode 11 lies in the shadow of the question asked in Episode 10, namely p.A21, LL.35-39. That question was judged as R-h. Since no model has been presented since that question, the judgment also holds for this episode.
LL.8-36: II-d.
L.36-p.A23, L.8: II-d (although that the experiment is "easiest" is hardly a substantive reason for acknowledging the pupil's response).

Judge B: R/ID

L.7-36: II-e.
LL.22-25: II-a.
LL.31-34: R-h.
L.34: ID-a, b.
p.A23, LL.1-8: ID-d.

Judge C: R/ID

L.14: ID-e.
L.26: ID-e (here the result for which the experiment is being considered is presupposed, hence the decision is not made on rational grounds, p.A28, LL.3-6).
LL.31-34: ID-a.
p.A23, L.1: ID-d.

Teacher: All right. Heat up the water while it's dissolving. Now, I had sort of gone over the experiments thinking which one would be the easiest, and I think potassium permanganate actually would be. I have two beakers. One...or both of them have water in them. One of them I'm going to put...or in both of them I'll put potassium permanganate. Now if we compare it...the speed at which we have...or, I'm sorry, the way that heat affects the speed at which the substance moves or dissolves, we have to go about it by doing what? We've got two of them, what do we do with each one? Comparing the way heat affects the speed. Ron.

Ron: Heat one and cool the other?

Teacher: Okay. Simple as that. Now they're both at the same temperature--just at the temperature at which the water came out of the tap. I'll leave one with the potassium permanganate in it, and I'll heat...heat the other one. Now I'm using potassium permanganate because it's easy to see, and I think you should be able to get a view of it from where you're sitting all right. (Pause) Okay. Remember the other day I did this, I put it down the side...down the side very carefully so we don't get too much movement...(Solid potassium permanganate is added to one beaker and a purple color begins to spread throughout the water.) ...on its own. Well, you can see that's moving

EPISODE 12 (L.8 - p.A24, L.46)

<u>Judge A:</u> R/II

LL.14-26: ID-d.
LL.28-52: II-f.
p.A24, L.10: R-h (apparently when the teacher uses the term "diffuses" she is talking about the movement of molecules, see p.A14, LL.36-40).
p.A24, LL.40-46: II-a, f; R-h (see "diffusing issue", p.A24, L.10).

<u>Judge B:</u> R/ID

LL.14-35: ID-b, c, d, g.
p.A24, LL.25-36: ID-a, c; R-h.
p.A24, LL.41-46: R-h; ID-c, b.

<u>Judge C:</u> R/ID

This judgment is made since although evidence is presented throughout the episode, it is not clear which claim the evidence supports. If it is that diffusion is faster, then the explanation is not adequate.
L.27: ID-e (Ron's suggestion is accepted as "simple", but is then ignored).
p.A24, LL.41-42: R-b (a construct cannot have a visible effect).
p.A24, LL.41-45: ID-f (one cannot see if this is "diffusion" or "water currents"--only one explanation is being accepted).

already. Now we're going to compare it with the movement when it's heated. (Solid potassium permanganate is added to the second beaker of water.) Trying to get it as close to the same amount as possible. And once again, it diffuses as we showed... have shown before--we did this the other day. But... (pause) now, could I continue here...is it easier to see if I hold up something light behind it? (A piece of paper is held behind the first beaker.)

Pupil: Yes.

Teacher: Okay. Now we watch this as it's being heated. (A lighted bunsen burner is placed beneath the second beaker.) And, once again, compare it. Now, if you wanted to make this particularly accurate, we probably should take time measurements, see...and take, at certain intervals... "All right, after half a minute, what sort of results do you get?" But I think we can see, er, just visibly, what sort of difference we have. Now, the people up close, I think at least, can see the effect of the heat. Perhaps back further I hope you can see as well. What is the heat doing to the potassium permanganate? Terry.

Terry: It's diffusing much faster?

Teacher: All right. (Pause) Now, if you remember, I let it sit overnight the last time--maybe it was two days--

EPISODE 13 (L.46 - p.A26,L.25)

Judge A: R/ID

and it finally was dark all the way through. But it took a few hours before we get it diffusing through. But with the heat, we have it moving. Now, how did... what is causing the movement of that potassium permanganate from the bottom upwards? Heather.

Heather: The molecules are just moving faster than they usually do? Like it goes from a high concentration at the bottom to a low concentration through the whole.

Teacher: Right. What are we...what have we added to this experiment? Cathy.

Cathy: Heat?

Teacher: Right. And what is heat? Brian.

Brian: Energy.

Teacher: All right. So what conclusion can we draw concerning heat and speed of movement? Stephanie.

Stephanie: Um. Heat speeds up the movement of molecules?

Teacher: All right. And so the heat is actually cau this to move up. Now we could say, "All right, it's ...it's currents in the water--the water currents." Is...what causes the water currents, though? Kim.

Kim: The heat.

Teacher: All right. So it's indirectly the heat energy. Whether it's the water currents or not, the molecules still are moving.

L.4: R-h.
LL.7-17: ID-c, d, g; R-b, h.
LL.24-30: ID-c; R-b, h.
LL.39-43: ID-c.
L.43: R-b, h.
p.A26, LL.1-7: ID-a, c (Interview p.A37).
p.A26, LL.1-7: R-b, h.
p.A26, LL.19-21: II-f.
p.A26, L.24: R-h.

<u>Judge B:</u> R/ID

LL.11-32: R-b, h; ID-c.
LL.11-24: ID-b, d.
LL.24-43: ID-a.
L.41-p.A26, L.8: R-b.
p.A26, LL.1-7: ID-a, b, d (Interview p.A37, LL.4-30).

<u>Judge C:</u> R/II

L.11: R-b.
L.14: ID-d.
LL.21-24: R-i, b; ID-b (the intellectual backing for this statement is as before).
LL.30-35: ID-g; II-f (two ways of explaining the phenomena are offered, diffusion--movement of molecules and currents--movement of whole mass. No means for judging the teacher's explanation, although the viability of model is clear.
p.A26, LL.1-4: R-a.
p.A26, LL.7-11: II-b (Anne-Marie's response is considered as supported by argument). This piece is confusing for the type of motion being called for is translational. The assertion can come from the principle "all molecules move"--diffuse, contradicts what is said earlier about movement coming to a halt, p.A13, LL.38-41 and p.A14, LL.1-4.

Now is it only the potassium permanganate molecules that will be moving here? Anne-Marie.

Anne-Marie: The water molecules will be moving too.

Teacher: Right. So we get movement of both. Now I... from where I'm looking, it looks as though it's getting pretty dense right now. (The water in the heated beaker is almost entirely a uniform dark purple color, while there is little coloration in the first beaker.) There's still quite a bit on the bottom, but you can see a very strong difference between these two--just sitting there at slightly cooler than room temperature out of the tap. It doesn't diffuse very quickly. Yes, Heather.

Heather: When it's a high concentration and its, er, a light color, how come when it spreads out more it's darker and more dense?

Teacher: Oh, okay. Er, I think if I have your question straight, I'll answer it the way I think it is, I'm just going to shut this off. (The bunsen burner is extinguished.) Er, when potassium permanganate spreads out, it's...those crystals are really very concentrated. Now the very first wisps that come up make it look slightly pink. Now, it's, it's difficult to see where you are--there's a small problem with this--but the bottom of this, um, beaker is dark, dark purple and that's

EPISODE 14 (L.25 - p.A27, L.16)

Judge A: R/II

LL.39-41: ID-a (the "evidence" for high concentration is the very phenomenon the teacher is trying to explain--the answer to the pupil's question is okay, providing it is previously shown that the crystals are highly concentrated).
p.A27, L.4: R-h (again, the issue of "diffuse").
L.25-p.A27, L.16: II-e, h.

Judge B: R/ID

L.31-p.A27, L.16: II-e; R-h; ID-a, ID-b, f, g.

Judge C: R/II

LL.39-41: ID-a (movement from a high to a low concentration is already established, but that crystals have a high concentration is not).
L.40 and p.A27, L.2: R-i

the potassium permanganate in very, very high concentration. When it starts to diffuse up, that dark purple color is diluted, but there's enough potassium permanganate there to make it have a very, very dark color. So, even the amount of potassium permanganate I've added causes this dark color. Er, I have to add about two crystals to get it to stay a very light purple. It has a great deal of coloring effect. Al.

Al: If you, er, stirred it very...all of a sudden er, if you stirred the light one...

Teacher: This one?

Al: ...would it all go dark?

Teacher: Okay. Well, let's try it. Now, we've seen the results from these two. All right, you can give, I think, a good description of what's happened after several minutes with this... after several minutes with this one. (She stirs the first beaker.)

Al: Yes.

Teacher: All right. I've caused movement of molecules, but what was it caused by that time? What kind of force? Alan.

Alan: You.

Teacher: By me. Right, my force. External force in this case, then. Instead of the internal force, the external force is forcing it around. Any other questions? So we've shown that heat

(references to concentration as a "thing" or description, rather than as a way of speaking about phenomena).
p.A26, L.37-L.12: II-b (explanation is rational apart from the above point about crystals being concentrated).

EPISODE 15 (L.16 - p.A28, L.20)

<u>Judge A:</u> R/ID

LL.17-24: II-e.
LL.26-35: ID-c; R-b, h, i.
L.43: ID-c; R-h.
L.46-p.A28, L.3: ID-c; R-b, h.
p.A28, LL.3-6: ID-a (<u>that</u> was just asserted, see p.A15, LL.14-18).
p.A28, LL.17-20: ID-c; R-b, h.

<u>Judge B:</u> R/ID

LL.17-24: II-e, f.
LL.34-38: R-b; ID-a, f.
LL.41-43: R-h; ID-f (Interview p.A33, LL.29-32).
L.34-p.A28, L.6: ID-b, c, d.
L.45-p.A28, L.3: R-h; ID-b, c.

<u>Judge C:</u> R/ID

LL.16-34: II-e (Al's question is taken and answered by a demonstration).
LL.34-35: R-b.
LL.37-45: R-b; ID-g, b (the explanation is given in terms of two new constructs--external and internal force; there is no way to determine a link between this explanation and the one about energy; the argument for the presence of an internal force is absent).
p.A28, LL.3-6: ID-a (no evidence was presented for this "before", it was asserted).

affects diffusion by speeding up the movement of molecules. Before, we just knew that heat affected it, we didn't know in what way. All right? Now, for a note I've got a few points that we gathered from the previous experiments. I'll get a title down and a little bit more added to that. But before you get your books out though, I want you to get the information down on the board then describe this demonstration. I'll put the purpose down, "to find out the effect of heat on the speed of movement of the molecules." Stephanie?

Stephanie: Um, what energy like, that makes us walk?

Teacher: Okay. Anyone. What energy makes us walk? Al.

Al: Your own energy. Your muscles in your body. Well, it's, it's, it's you. Y'know. It's not, it's no ...it's no force like...if you add heat you'll walk faster or anything. It's just er...(laughter). It's sort of up to you.

Teacher: How about if someone yells? Sound energy...

Al: It's...well that's...

Teacher: ...would you walk faster?

Al: ...that's, that's difficult.

Teacher: Right. Heat inside you...I'm sorry, energy inside you, but what causes the energy?

EPISODE 16 (L.20 - p.A29, L.13)

Judge A: R/ID

LL.20-23: II-e (the whole episode concerns the pupil's question).
LL.20-23: R-h (during this entire episode, the conditions under which pupils can understand the concept of "energy" are absent, Interview p.A33).
LL.25-36: ID-e.
LL.36-42: ID-e.
LL.43-44: R-h.
L.44-p.A29, L.3: ID-d.
p.A29, LL.2-6: ID-d.
p.A29, LL.7-8: ID-a.
p.A29, LL.9-13: ID-a; R-h.

Judge B: R/ID

L.20-p.A29, L.13: R-h.
L.24: R-h.
LL.35-45: ID-e, f.
LL.42-45: ID-a, b.
p.A29, LL.1-4: ID-e.
p.A29, LL.2-14: ID-a, b, c, g.
p.A29, LL.5-6: ID-d.
p.A29, LL.6-13: R-h, i.
p.A29, LL.7-13: R-a.

Pupil: The brain.

Teacher: What do you have to do to get energy to move? Okay, Cheryl.

Cheryl: Food. Eat food.

Teacher: All right. Eat food. Inside your body the food is chemically changed. It's a chemical type of energy--gives your, your muscles a type of energy that eventually propels you...causes you to move. Terry.

Terry: Um. You want us to copy down that information on the board?

Teacher: Yes. I'm just going to write a little bit more on top...get the title down and so on, all right?

Terry: Okay.

Teacher: Okay. Will you take your notebooks out please. (Pause, some comments are made.) Come on, quickly and quietly please. (Pause, above the previous board work is written, "Matter and Molecules. What information has been gathered from the previous experiments." The words, "of molecules" are added to numbers one and two of the previous board work. Then, "Experiment 3. Purpose: To find the effect of heat on the movement of molecules. Describe the Experiment to show the above." There is some noise.) Alan. Are you having problems:

Alan: No.

<u>Judge C:</u> R/ID

p.A28, L.24: R-b.
p.A28, L.42: ID-a.
L.2: ID-e.
LL.6-13: ID-a, f, g.

EPISODE 17 (L.14 - p.A31, L.5)

<u>Judge A:</u> R

Procedural--no judgment re Category 2. Category 1, R.
LL.37-40: R-b, h.
p.A30, LL.27-28: R-b, h.

<u>Judge B:</u> Procedural only

<u>Judge C:</u> Procedural only

Teacher: Okay, behave. (A long pause as pupils write. The teacher writes on the board "POTASSIUM PERMANGANATE".) Just so you'll know how to write "potassium permanganate". (As pupils continue writing, comments are exchanged quietly. Some ask questions of the teacher.)

Pupil: In the cool, sort of er...in the light one that we saw, do we put down that it's purple?

Teacher: What it really did from the start. (Pause) Oh, that's right. Don't forget the test tomorrow...

Pupils: Oh. No. (additional groaning).

Teacher: ...starts at static electricity and up until what we've done now. The only thing from static electricity that will not be on is the drawing of atoms--you don't have to know that. (Pupils continue writing.) Brian.

Brian: Do we draw a picture?

Teacher: Sure.

Brian: Right.

Teacher: Make sure that you have enough description down as well as the diagram...help you remember it. (Writing continues. School announcements are made over the address system. Pause) You may take your textbook home overnight if you wish, or keep the ones you took last night. Would you please bring them back tomorrow. Put them back up

on the shelf. (Pause) If you didn't get the experiment completed finish it tomorrow night. Study tonight. (Pause) Okay.

(The lesson ends.)

TRANSCRIBED INTERVIEW FOR

"THE MOVEMENT OF ATOMS AND MOLECULES"

(The interview begins.)

Interviewer: Look, some of these questions may well sound just a little foolish...

Teacher: That's all right.

I: ...but I want to make sure I get all the information.

T: Sure. Fine.

I: I got the impression that the kids were a little bothered by the taping.

T: A little bit, I think. This class has been...not, I don't think "bothered" as far as nervous about it but just, they get kind of giddy when they know that somebody's taping them. You know, it's just...

I: I guess that's understandable.

T: I think so.

I: Okay. The...about half-way through the class, you were talking of ways in which one of the experiments that had been earlier could be adapted to show the heat effects.

T: Er, right.

I: And one girl suggested the two glass jars. Very little else was said to sort of describe what the experiment was and I was wondering if you would...

T: Yes, sure. I took, I put ammonium hydroxide in--just a small amount --in one, they were gas bottles. And, er hydrochloric acid in the other. When they meet they make a cloud, a white cloud. And ammonium hydroxide is essentially lighter than air...that's true, and then hydrochloric acid is heavier so you put one on top of the other--ammonium hydroxide on top of the other, and a plate in between. As soon as you remove that plate you see the gases churning and forming ammonium chloride...

I: Right, they know...

T: ...so that they knew what it was about because we had done it...

I: I see.

T: It didn't make too much sense, I guess, when you...

I: Did they do a separate experiment to determine that the ammonia was lighter than air?

T: No. That was, er...not right now. Now we had done some...oh, let me see. I think it was, it was not an experiment but some problems when we were in density way back when, that we had come up with some information concerning these substances and then we used it when we got through here ...at this far.

I: Right. Um, energy features a number of times in the lesson. The kids came up with "There are forms of energy: heat, light, and sound." Um, I'm interested in what you think they understand by the word "energy", it's sort of a difficult word for them.

T: Right. Not too much right now. The second...this course is divided into two major parts: matter and energy. The "matter" part takes up most of the year, and we're finding out more and more as we...well, we've gone through it last year and this year. And we start taking energy as such, calorimic measurements and so on near the end of the year. So, so far energy really is just a word, I think. They aren't...

I: Does it refer to a thing, a process, or...what?

T: Something appo...something other than matter. Matter that they know as something that has mass and occupies space. Well, energy doesn't. It's...sort of intangible something or other. And we haven't gone really into any more detail than that because that comes up as a separate topic...

I: Umhm.

T: ...which we take in another couple of weeks.

I: Is it somewhat similar to the word "force"? That was mentioned when you talked about stirring...

T: Uh-huh. We had talked...

I: ...when you stirred the solution?

T: ...about. Right. We had...we've taken some about force. They know that it's a push or a pull. You know, we've gone through that before. So they know a fair amount of information about forces and they've taken pressure and point forces, and so on.

I: Most of the other questions I have concern, um...their understanding of "molecule" and "atom". They've clearly done a lot of experiments, and seen a lot of experiments which show different phenomena. And I'm very curious as to what they understand by the word "molecule".

T: All right. We've done...we started off with atoms of course, and we did drawings of them so that they know what composes atoms. We've taken some work with static electricity so that they know that parts of atoms--the electrons--can move about. We have done, um...very little work as

far as, er...let me see, as far as other than saying that we've...that if you combine two or more atoms you get a molecule. Now they...most of them knew that water is like H_2O and that meant three atoms and you had a molecule. They know what elements are as far as having individual atoms--we've done that. And they know that compounds are composed of molecules. Um, it would certainly help if you had a copy of our--I haven't got one here--copy of our...oh, outline...

I: Umhm.

T: ...year's outline. Because what comes up are...we go into some chemistry, we go into, er...size of molecules, er combinations of atoms to make, you know...oxygen gas is composed of two atoms of oxygen, and so on...that we do go into some chemical work with it and I think it gets across a bit more what a molecule actually is. So they know what an atom...what an, right, what an atom looks like as far as drawing one three-dimensionally. They know it's three dimensions, and so on. But we haven't done any...too much work really with the molecules as far as compounds and reactions and so on. We do, hopefully, hit a little bit of that coming up in the near future.

I: Umhm. They're...the talk about molecular theory then is sort of central to this part of the course. (There is an interruption, another teacher enters the room looking for some glassware.) We're talking about molecular theory. Do you think that the youngsters understand the words "theory" and "concept" as referring to something quite different than other ways in which we speak of the world? How do you think they take that?

T: Oh dear. I don't know whether at grade nine level, whether they really understand "theory" as being one of these or just something where we say that it probably happens. I don't know whether...wow...(pause) I really don't think they grasp it that well. I think they have to get into more of it, take more of it as far as theory goes. A lot of the things that we do this year we say, "Okay this is a fact and that's a fact, something else is a fact." And we've either proven it through problems or experiments or whatever. But, they seem to accept things as being either black or white, right or wrong. I think that they have trouble sort of, coming up with the ideas, you know...more theories sort of thing.

I: Umhm.

T: And I think they have to be, um...associated with it more. I think it improves as they go along.

I: Umhm. Well, that may be...

T: I don't know whether that's what you meant.

I: ...that may be. That's the sort of thing I mean. So, when you speak of...they understand that molecules--as you just said--are sort of three-dimensional, then they don't see this as a model, but they see it as an

actuality? Is that the way that they're sort of approaching it?

T: Hmm. You're saying that they see it as a model, or not, or no? Which, which way round...sorry about that?

I: I'm saying they see it as an actuality. That that is the way they are...

T: I think...

I: ...rather than as a model, perhaps.

T: I find that the grade nines tend to believe what you say.

I: Umhm.

T: And if you say "It's three-dimensional, and that's the way it is." Okay. Well, they'll accept it. Some of them question it and say, "How do you know?" But they tend to accept it as such. Now, they can't picture it, I don't think...they can't picture an atom as being as small as it is. Well, you know, I even have trouble thinking of it as small as it is. But they all realize, I think, that there are small particles that make up...um, everything. But they just...they don't realize how tiny they are. They know, supposedly, what they're supposed to be composed of because we've drawn diagrams of them. But they can't actually picture...they figure them as being something that, well..."If you really tried you maybe can see them."

I: I'd like to go back to a few things left in the lesson. You're talking about the compactness of these things called "molecules" and how you can't walk through a bench, you might be able to walk through a paper, you can walk through air, and this sort of thing. Um...have they done any work, any experimental work which might lead them to believe somehow that molecules are of different sizes, as opposed to different distances apart?

T: Um...

I: Or that molecules can't be broken down, or some can and some can't, that's why you can't go through...

T: No, no we haven't...we haven't really covered that as yet. Er... trying to remember what's coming up. I don't know whether there's anything that we do that tells us size of molecules.

I: Or that they do have different sizes.

T: Uhuh...I...I don't think that there is an experiment that we do with ...that they...I can't think of one. I think the only way that we get around that is to say that the atoms, like all oxygen atoms are the same size, and I think they accept that after drawing pictures of them. Okay, "All oxygen atoms have eight electrons and eight protons in them" you know, and so on. So it has, they all have to be the same size. And

then they realize if you have water, "Well that's two hydrogen with an oxygen added, so that's a size--some size. And then if you have methanol, which has um...four hydrogens, an oxygen and a carbon, okay. Well, it's automatically bigger because it has, you know, the extra ones attached." From that they can...we, I...there was an experiment that we did just at the beginning of this section with methanol and water--combining volumes of each, and you end up with what should be bigger because of the molecules going into the spaces. Oh! That's what we did (laughing). Oh dear.

I: It all comes back to you (laughing).

T: Right. That's right. Oh...boy, is that ever silly!

I: Okay. Well, the reason I asked that was because you go from the experiment where you have ammonia in one end and chlorine, HCl in the other end, and you get some diffusion and you get white powder in the middle. And you say, "Aha. They're moving at different speeds." And from there you go to density. Um, and from density you go to mass, but you can't go from density to mass unless you know something about volume.

T: Oh right. Uhuh. We've done...

I: I wondered if that had been covered.

T: Yes we've done...as far as that, as density and volume and mass, we've gone through that, and we've done that experiment rela...so much that I've forgotten about it (laughing)...boy.

I. Okay. Um...let's see. There's one other thing I've just remembered. I didn't write it on this pad, but I had it down here. Something that one of the youngsters said that was very interesting. (Pause) I've taken copious notes, but I can't read a word...

T: Good heavens.

I: Well, some of the notes are odd things that are said by the kids so I have a track of the questions I have and where they come on the recording. So when I transcribe I think I can put it together. (Pause) I really think that has escaped me...(Pause)...in which case it couldn't have been that important or something! (Pause) There's something I was curious about...I'm really sorry. Can you think of what it could've been, Tom? (Laughter)

T: I'm glad to see somebody else forgets things too.

I: Oh, yes. It's so easy to do when you're sort of "on line" with this thing going, and you really wonder where you are.

T: I hope you've got lots of tape.

I: I've got over an hour on there...I'm not going...

T: What do you do? Chop it...chop it up after...

I: I just transcribe it and, if there's a pause like this, I'll say, "Pause while interviewer gets lost in his notes" or something. (Laughter, pause.) Oh yes, I remember what it was. It's when you do the heating effect with the potassium permanganate, and you have two beakers--one you heat and one you don't. And, toward the end of it you asked the question, (pause) "Which..." the question is either, "Which molecules are moving?" or "Are both the water and the potassium permanganate molecules moving?" And to a man they decided that it was...that both the molecules were moving. Why would they decide that...

T: Um. Why would they?

I: ...given that, you know, we can't see it?

T: No, we can't see the water moving. We can see the others moving. (Pause) I don't know why they would know...

I: Yeh.

T: ...necessarily. They did though, didn't they? Um...

I: Well, whether they knew or not or whether it was...

T: Whether they just...they just took a guess.

I: An educated guess?

T: It could be...it could be an educated guess or a...

I: In which case it would be based on something, now. Do you have any idea what it might be based on?

T: (Pause) I can't think of anything particular it would be based on, just that they gathered that the...that the heat's heating the water so the water would have to be moving as well. Er, they may have...um, they haven't done anything like that, unless they had some knowledge before. I don't know in the public schools whether maybe they do things ...you know, convention...convection currents in water and so on. So they may have some information on that--not from this year though they wouldn't have done anything with that at all.

I: Okay. (Pause) I have no questions left to do with what I saw. I really enjoyed that and I think you have a nice group of kids.

T: This is my best class. I enjoy this class. It's er...it's smaller then the rest. And a lot of eager students in it. They get very, um... oh, what do you say...when they're being taped. Usually they are more inquisitive, I guess, and they...more giggly and things going on with the lesson, you know. They sort of ask questions, and sort of batter back and forth more than they do than in this one.

I: Yes, yes.

T: But there's a lot of good kids in that class. I really enjoy this one.

I: Okay. I really should thank you because I know that it must be hellish having someone sitting...two people at the back.

T: The worst part is thinking about it beforehand.

I: Umhm.

T: While it's going on, you don't notice it. Just thinking about it beforehand. Oh dear...(laughs).

I: The, er...

T: This class by the way has been taped on video-tape for a parent's night that we did with them...on video.

I: I wondered why a couple of them said "Oh, we're being taped again" as they came in.

T: Yes. Uhuh. It was video-tape that time...(A description of the video-taping follows during which the recorder is switched off.)

(The interview ends.)

TRANSCRIBED SCIENCE LESSON:

"A PARTICLE MODEL OF LIGHT"

(The lesson begins.)

Teacher: Okay, I think we can probably get started. Would you clear off your desks, everything. (Pupils settle in their places.) Er, we have a recording in session, when you answer a question this morning will you try to speak for the microphone. A normal level instead of a whisper would be appreciated. Okay. (He writes "Light" on the board.) We have been dealing with light, and whenever we deal with the phenomena--physical phenomena, what is the first thing we do?

EPISODE 1 (L.1 - p.A41, L.5)

I/II

The first 12 lines contain procedural matter only, and the remainder of this episode appears to be a form of recall, as substantiated by some of the initial content of the interview (p.A64, L.33 and p.A65, L.19). Thus responses of pupils appear to be derived from previous experiences.

LL.20-21: I-a, h. It is clear from the interview that the distinction between phenomena and models has been made (Interview p.A65, LL.45-48) as it is in L.17, above.

Pupil: Observe what it does under certain conditions?

Teacher: Okay. Anyone else word that question in a slightly different way?

L.22: II-d, the reasons presumably being a recounting of previous work, as found in the body of the interview.

Pupil: How it behaves?

Teacher: How it behaves. Now we have studied what aspect of light, what phenomenon? David.

David: Reflection?

Teacher: Okay. So we know a little bit about reflection. (He writes, "Reflection" on the board.) What can you tell me about reflection? Julie.

L.31: II-d, as suggested in the interview, p.A65, LL.4-19.

Julie: Um. Re...flect (some laughter).

Teacher: Can you tell me anything?

Julie: Um.

Teacher: Would you like to stand up, please (some laughter).

It is acknowledged in this analysis that the scheme is probably unsuited for an epistemological analysis of recalled material, since it is designed firstly for the analysis of newly introduced knowledge claims. All the same, the scheme can be used to analyze the treatment of responses, such as Julie's.

Julie: Um. Don't you have to have a shiny surface or a light surface to reflect something?

Teacher: All right. What...

Julie: Or a smooth surface?

Teacher: Okay. What do you normally use?

L.11: II-e. Here, the teacher appears to want Julie to provide an example in order that the concept "shiny surface", L.8, is understood.

LL.13-14: II-e, substantiating the above analysis.

Julie: A mirror? (Some laughter)

Teacher: Okay. Barry?

Barry: Um, without reflection we couldn't see anything. Without reflection we couldn't see anything. In order to see anything we have to have reflection.

L.17: II-d. It is established in the interview (p.A65, LL.6-19) that mirrors have been used by the class in previous lessons.

Teacher: Okay. Anything else? Mary. (No response) Mary. (Pause) All right, I'll give you a specific question, Mary. Er, there is...there only one type of reflection?

L.24: It is not possible to characterize this response to Barry, since the substance of the interview fails to reveal if the claim in LL.21-23 has been substantiated previously.

Mary: No.

Teacher: What kinds?

Mary: There is normal reflection and ...fuse reflection?

Teacher: What was the second one? (Pause) So anyone? Nancy.

Nancy: Diffuse?

L.39-p.A41, L.1: Again, there is nothing in the interview that enables one to analyze the teacher's

Teacher: Diffuse reflection. So there are two types (writing, "1. Regular. 2. Diffuse.")...regular or normal. Okay. Can anyone say something specific about regular reflection? Cathy. What rules for regular reflection? Any at all? (Pause) Earl.

Earl: Er, light comes down at an angle like that and it's, er, reflected off at the same angle only on the opposite side?

Teacher: Okay. Can you put that in a little more rigorous language...mathematical language?

Earl: Er. Well now, it comes down at a certain angle as to er reflect off from the surface, plane at the same angle...

Teacher: You've got the right idea. Try to put it in as few words as possible. What are we talking about? We're talking about two angles, put a name on the two angles.

Earl: Angle A and angle B.

Teacher: In terms of reflection, what is a mathematical statement about angle A and angle B?

Earl: Angle A equals angle B.

Teacher: Okay. Now, instead of saying angle A and angle B someone give me the vocabulary, yes?

Pupil: The angle of reflection equals the angle of incidence.

response to Nancy's answer.

EPISODE 2 (L.5 - p.A42, L.18)

I/II

In this episode, pupils are reporting on the experiment performed with pins on the previous day, as described in the interview, p.A65, LL.16-18.

LL.8-10: I-h.

L.16: II-d, since it can be assumed that this was found from the experiment referred to above.

LL.25-31: II-e. Here the teacher appears to want a crisper statement of the law. This he obtains (LL.37-38), but not at the expense of denying the correctness of Earl's responses in LL.11-15 and LL.20-24.

The form of the law given on p.A42, L.4 is derived from Earl's response in LL.37-38, above. The argument required for this step--that of applying different labels to the angles--is present: II-b.

Teacher: Okay. And instead of the long sentence one can summarize that...(to "1. Regular" he adds "$\angle i = \angle r$"). Now, if that's true there's one other minor rule. Barry? (No response) Anyone else? Tom.

Tom: When the light, when, when light reflects off a mirror or something it stays in the same plane?

Teacher: Okay. In the same plane (writing on the board, "in the same plane"). And that's about as far as we got. Now, that isn't much to work on but I'd like to try and see what we can do with light in suggesting a model for light. Remember our standard way of doing things. We take a look at the phenomena and then when we can't really understand the phenomena we say, "Okay. What does this...what does it behave like?" Any suggestions for a simple model for light. Light behaves as if it was... anything? No answers seem to be...(pause) what do you think light behaves like? Listen. We, we know about deflection. (Drawing on the board) Here we've got a plane surface and something coming down and something bouncing back. Have any of you seen anything in your vast experience which behaves that way? Sharon.

Sharon: A ball.

Teacher: A ball. Tremendous. (Holding a tennis

LL.5-7: I-i.

L.14: II-d. Again, it is assumed that the support for this "rule" appeared in the experiment referred to in the interview, p.A65, LL.16-19.

EPISODE 3 (L.18 - p.A44, L.9)

I/II

LL.18-30: I-a, h. Throughout this section, the teacher indicates the fashion in which "model" is to be understood. His question ending on L.30 provides pupils with a clear distinction between the logical status of "model-talk" and "phenomena-talk".

LL.30-37: Here opportunity is provided for pupils to suggest appropriate models to account for the phenomena they have experienced. This might then be characterized as II-f. Yet, the viability of any suggested models is not the question, so such a characterization is not strictly accurate. Indeed, it is more appropriate to regard the manner in which suggested models are treated later in the episode.

ball) So, I just happen to have a ball (some laughter). Now, there are a set of rules and I want you to see, just check this out. If, if this going to be a model it'll have to work the same way. (Bouncing the ball on the desk so that it lobs among pupils) If I bounce the ball...(laughter). (The ball is bounced along the front bench in a series of arcs.) Now, did that look like light?

Pupil: No...

Pupil: Like a...(indistinct)

Teacher: Okay.

Pupil: Bounced too many times.

Teacher (bouncing the ball as before): Bounced too many times. What about the angle, that's the important thing?

Pupil: Yeh, it looks pretty good.

Teacher: You think the angle of incidence equals the angle of reflection (bouncing the ball again).

Pupil: Yeh. No, it would be...

Teacher: Mary.

Mary: It goes down on an angle of up straight... (some laughter)...straight up...a right angle.

Teacher: The ball?

Mary: Yeh.

LL.3-8: The teacher provides the "rules" and thus, the basis upon which claims about the model's suitability can be judged, II-a, b.

The bouncing of the ball clearly provides pupils with evidence by which the ball model can be found appropriate or inappropriate, thus:

LL.8-10: II-f, and

LL.12-14: II-f.

L.26: Presumably this pupil is examining the relationship between the angle of incidence and the angle of reflection. Evidence is therefore being supplied: II-a.

LL.35-38: There is a discrepancy between Mary's observation and that of the pupil speaking in L.26.

p.A44, LL.1-2: The teacher fails to respond to the discrepancy mentioned by Mary: ID-d, h. Instead, Barry is required to judge the

Teacher: Okay, I'll tell you why...let's try it again. (Bouncing the ball along the bench) What do you think of our model of light so far? Barry..

model and, on the basis of its apparent inadequacy, it is altered.

L.8: II-f.

Barry: Pretty lousy.

Teacher: Pretty lousy model. Okay. So, if a ball doesn't work in its form as we did it we have to start qualifying our model right away. We can put some limitations on our model. What limitations? Greg. (No response) How can we make the ball behave so that the angle of incidence equals the angle of reflection? What do we have to do? Nancy.

EPISODE 4 (L.9 - p.A45, L.33)

I/II

LL.9-15: I-a, i. If the model were not conceptual in origin, adaptations could not be made it.

Nancy: You can bounce it against something.

Teacher: I just did bounce it against something--to the desk.

LL.24-26: II-d. The teacher uses the previous demonstration to respond to Nancy's suggestion.

Nancy: Well, hit sort of, like, another object.

Teacher: It did hit the desk. Yes.

LL.29-30: II-d.

Pupil: You have to use a certain amount of force.

Teacher: Okay, and what... if I put more force on the ball, what's going to happen to the ball?

Pupil: It's going to go... it's going to go, er...

LL.33-36: II-e. The teacher appears to demand how such a limitation on the model will alter it, this being one way in which such a response to the initial question (LL.17-20) could be treated with regard to reason.

Pupil (quietly): Through a glass window and break it.

Teacher: Anybody?

Pupil: Er, it'll bounce off there at different angles?

Teacher: Okay. But what's going to happen to a ball before it hits the desk? I'm going to put some force on it (throwing the ball harder at the desk so that it strikes the surface obliquely and bounces)...what's the difference between--let it go--and the force on that? In terms of the ball, what happens to the ball when you put a larger force on it? Bob.

L.3: ID-e. It seems that this response is disregarded or misunderstood, for the teacher fails to follow it up or to request amplification.

LL.6-16: II-c. Here the model is being adapted in one respect--making the ball go faster. This approximation to linearity corresponds to the phenomena being accounted for--the linear reflection of light (p.A41, LL.43-45).

Bob: It goes straight and gives just a...(indistinct).

Teacher: Okay, could you repeat that?

Bob: It goes straight.

Teacher: It straightens out first of all.

Bob: Yes.

LL.22-23: II-a. The preceding demonstration supports this assertion--the assertion itself being initially offered by Bob (LL.17-18).

Teacher: Instead of falling in an arc, it goes straight. Why does it go straight? Julie.

LL.26-26: II-a

Julie: Because it's going at a faster speed?

LL.29-30: II-d: Julie has noted this from the demonstration, it seems.

Teacher: Okay. Number one: we have to make the ball go faster. Now, think for a minute. We're trying to make the ball behave just as light behaves. What about light and how fast it travels? You come into a room, the room is dark and you turn on the light. How many seconds does it take before you see the light?

EPISODE 5 (L.33 - p.A47, L.3)

I/ID

LL.34-36: I-a. This comment again provides pupils with the notion that a model is something conceptual.

Pupil (quietly): One.

Teacher: Greg.

Greg: I would think less than a second...can't really tell the difference.

Teacher: Can't hear you.

Greg: Can't really see the difference, it goes so fast.

Teacher: So it goes...? Yes.

Pupil: Faster?

Teacher: It goes very fast. Anyone happen to know what the speed of light...speed of light, Dave?

Dave: 186,000 miles per second.

Teacher: Extremely fast. So the number one limitation on our model: we'll have to make the particle go very fast. So, (indicating a pupil) do you want to go out and catch this because it'll probably come off. If I throw it--I'm not going to throw it really hard--(the ball is thrown again and appears to travel off the bench in a straight line) throw it a little bit harder and just watch the angle...(laughter as the pupil fails to catch the ball). Watch it closely, okay...throw it a little bit faster (throwing the ball again). And if we had a camera--a movie camera--we could probably capture this and measure the angle. And I think we could prove that the faster the ball went, the closer

L.2: ID-d

p.A45, L.36-L.18: The teacher attempts to establish that light travels "extremely fast". From the interview (p.A66, LL.15-26) it is clear that pupils have not talked previously of this in class. Thus the teacher's claim in L.18 can be characterized as ID-a despite pupils' contributions to this, for no quantitative treatment is provided Thus, pupils cannot tell at what speed the ball must move in order that the rule "angle of incidence equals angle of reflection" is approximated.

L.18: ID-d.

LL.20-22: I-a, for the same reasons as given for the analysis on p.A44, LL.9-15.

LL.22-38: This portion contains some procedural commentary on the throwing and retrieval of the tennis ball.

L.38-p.A48, L.1: ID-a. Although pupils can observe the angles qualitatively, no provision is made for a quantitative establishment of the rule "angle of incidence equals angle of reflection".

it would obey this law. So, okay. We can force the ball in that situation. Now, there is something else about the ball we should mention.

Pupil: It's light and the gravity will pull it down? Like that's...

Teacher: I don't think...

Pupil: ...that's why you have to throw it hard.

Teacher: Okay, all right. You're right. After, as far as the ball is concerned, you have to increase the speed to overcome gravity. Bob.

Bob: It's has to, er, be bouncing?

Teacher: Good. When it collides, it has to bounce. Now, can anyone express that in a slightly different way? Mike.

Mike: Well, when it collides with the surface of the desk it gives in kind of? Like it...like, when it hits the bottom of the ball it gives in and lets go again, and comes back.

Teacher: All right. If you notice, er we'll do a quick experiment. (Releasing the ball so that it falls to the desk vertically) Watch how high the ball comes up again when I drop it. (Marking a point about half-way between the point of release and the bench top) About like that, okay? Now, if I was going to deal with light, how

EPISODE 6 (L.4 - p.A48, L.13)

R/ID

LL.7-9 and LL.11-12: Here it is unclear if the pupil is offering something novel, or if the effort is an explanation for the need to increase the speed of the ball.

LL.13-18: R-a; ID-d, a. The argument linking speed with "overcoming gravity" is absent. Furthermore, "gravity" is talked about as if it had a physical existence, for in that way only could it be thought of as something to be overcome.

LL.21-22: II-d. Presumably, "bouncing" and "reflecting" are being taken as synonymous, as indicated by the teacher's speech on p.A42, LL.39-46.

LL.33-44: II-d. Here the focus appears to be on the last part of Mike's statement "...and comes back". The teacher demonstrates that the ball fails to attain the height from which it was released, thus providing the reason for indicating that Mike's response was partly incorrect.

high do you think that I should have the particle come back again? (Pause) Anyone. Jennifer, what do you think? (No response) How high here? Well, what ...put it the other way around, Jennifer. Why didn't the ball come up as high?

Jennifer: It lost speed when it hit the desk.

L.13: ID-d. Jennifer's explanation is accepted without reasons.

Teacher: Okay. Now, if I take a mirror and we shine some light on the mirror. The light coming off the mirror...can you tell the difference between light before it hit the mirror and the light after it hit the mirror? Jennifer.

EPISODE 7 (L.13 - p.A49, L.43)

I/ID

Jennifer: It's not as bright when it comes off the mirror.

Teacher: Maybe. Have you got any proof for that?

LL.25-26: II-e. The point is honored through the request for support.

Jennifer: Umhm.

Teacher: Anybody support that statement from direct viewing?

Pupil: Well, when we did that, um, experiment with the light and we had it going with the small mirror and when the first reflection was rather less than... (indistinct)

LL.31-36: Here the pupil seems to refer to an observation obtained during one of the experiments described in the interview (p.A65, LL-4-19).

Teacher: Okay. I'll have to accept that if that's what you saw. We were talking about...different things about...trying to straighten it out here. When the ball bounces--getting back to our point

LL.38-40: ID-h. Although this conflicting observation is honored, no attempt is made to resolve the conflict rationally.

here--it loses what? Anyone know the word? "Speed", but there's another word.

Pupils: Momentum...momentum? Energy. Energy?

Teacher: "Energy" I think is the word for further topic. When the light bounces off the material, some of it may be absorbed. So the quantity, the amount of light may change, but the type of light... the energy of the light does not change. So that in this case we want a particle which does what? Jennifer. In order to have it not change energy, how high must it bounce?

Jennifer (quietly): The same height as your hand was?

Teacher: Can't hear you.

Jennifer: The same height as your hand was.

Teacher: Okay. We should have a particle which, when it bounces, doesn't lose energy. So that's two things: we have to have a high speed particle, we have to have a particle which doesn't lose energy. Now the tennis ball doesn't fit either one of these categories very well, but we can still use it as a model because we can envision a ball which is going at very high speed and which doesn't lose energy when it bounces off. Now what about...there's another obvious property? Jan.

LL.1-3: This appears to recall Jennifer's point on p.A48, LL.11-12.

L.6: From the interview (p.A67, LL.27-33) it is not clear that this concept, "energy", is understood. Thus, LL.8-10: ID-a.

LL.11-15: ID-a, b. It seems that this explanation is advanced to overcome the pupil's report of the conflicting observation on p.A48, LL.31-36. But the argument is not presented in the current portion.

LL.31-34: ID-a. The model requires that no "energy" is lost in collision, but it has not been established that light behaves in such a fashion, as noted above.
LL.35-37: II-a. The features of the model have been demonstrated.

LL.37-43: I-a, h. Pupils are provided with the notion that the model is a way of "envisioning light".

EPISODE 8 (L.44 - p.A51, L.7)

I/ID

Jan: It has to be perfectly smooth?

Teacher: Well, in the case of a ball, I suppose that would help its bounce... bouncing properties. Er, anything else? Nancy, pardon.

Nancy: When light reflects off an object some of it is absorbed but a lot of it will be reflected.

Teacher: Okay. You're getting into the complicated properties which we haven't discussed yet in terms of real light let alone a model. Let's stick with the model of reflection first of all. One obvious property? Yes.

Pupil: Well, it has to be round.

Teacher: We said it was a sphere. Oh, come on. This is so easy. You can't see anything about that ball which you'd like to change to make it better?

Pupil: Make it more streamlined? (Some laughter)

Teacher: Yes?

Pupil: Have it come in different colors.

Teacher: Okay. Maybe. That would...you want to get into the complicated part of this, I want to stay with the simple part. What about the size of the ball? What'll we do with the size?

Pupil: Er, make it smaller?

LL.3-6: ID-d. Despite the attention given to Jan's response, the substance of it is not incorporated into the model.

LL.13-18: ID-d. Nancy may be recalling some of the teacher's previous argument (p.A49, LL.8-10); but the teacher fails to account for this suggestion in the model.

LL.6-39: ID-b. In this section the teacher is asking for something but failing to provide "clues" that pupils might be able to structure into an argument for attaining the apparently desired response.

LL.24-25: II-d. assuming that the pupils understand that the term "spherical" may be applied to the ball.

L.32: ID-d. As noted in the analysis of LL.6-39, above, no reasons are provided so that pupils might be able to obtain the response by their own reasoning.
L.35: ID-d.

LL.40-41: The "clue" is provided.

Teacher: Okay. We don't see any big blobs of light bouncing off the wall... (some laughter). So in our particle theory, the limitations on the particle we have to imagine. Now, you remember, a model is something, er--even though we use physical models--the essence of the model is something in your mind. The essence is a mathematical model. We want to analyze light in terms of a ball, and another word for a ball is a particle, because we want to shrink it down and make it go much faster, and it gives the property that it doesn't lose energy. I am talking about a very small particle that has certain properties. And so we've got to call this "the particle theory". (Writing, "Particle Theory" on the board) Now the particle theory, with those limitations successfully explains reflection. We can imagine a ball or particle reflecting having these properties. Now what I want to do is take this one step further, and see whether or not we can use the particle theory to predict something about light. If it's a good theory, if it's a good model, what the model tells us will be true for light. So the process here is... this is why, when we talked about models in the first of the year, we couldn't really answer the question "What was a model?" because we didn't have enough background, enough experience. Now we have observed a few different phenomena--namely,

LL.1-3: ID-a, b. Since light is not observed as discrete particles either, the argument is incomplete.

L.7: I-a.

EPISODE 9 (L.7 - p.A52, L.21)

I/II

LL.10-12: I-a.

LL.25-26: I-h.

LL.28-31: I-i.

LL.31-34: II-c. Up to this point the lesson has been concerned with illustrating how the model can be made to correspond with phenomena.

LL.40-43: II-b. The argument is presented for determining the usefulness of the model in advance.

LL.45-51: A procedural point is introduced.

L.52-p.A52, L.21: I-h. In this section, the teacher emphasizes

light. We're going to build a model of light. And now I think you can probably get the beginnings of what a model is. We look at a phenomenon. We suggest a theory for it. And now we're going to try and apply the theory to predict something about the nature of light, and then we're going to go back and we're going to say "Does light behave that way?" If light behaves that way we can start all over again and say "Uhuh, that theory's okay." And we'll just keep on circling and building up our knowledge about light. So, is there anyone, first of all, who disagrees that a pall... a ball or a particle can be made to reflect the same way as light? First of all, we haven't checked this part: does the ball bounce in the same plane? Does the line between that point and myself...if I throw the ball in that direction will it bounce out into the room?

Pupil: It depends upon what kind of surface, surface that it hits. It usually comes off the desk and goes way out here.

Teacher: Okay. I can't put any spin on the ball, for example. I can't... (bouncing the ball) I don't know whether this will work, but...If I try spinning the ball...(the ball deflects from the plane in which it is thrown) it didn't stay in the same plane, it moved off slightly. I don't know if you can see that, if I do it

the nature of the model--that it is conceptual, and gives advance notice of how the model is to be used to make a prediction. Thus, although material in this portion of teaching can be classified as procedural, it serves to provide further evidence of the Instrumentalist view of science provied for in this lesson.

EPISODE 10 (L.21 - p.A53, L.35)

I/II

LL.21-26: II-f.

LL.28-29: The characteristics mentioned here have appeared previously in the lesson on p.A42, LL.10-13. It appears that these are to be put to a test in what follows.

LL.39-50: ID-e. The teacher talks to the matter of placing a "spin" on the ball, whereas the pupil's comment has to do with the type of surface used in bouncing the ball.

over this way you might see it a bit better. (The ball is bounced toward the class and is seen to swerve.) Instead of going straight out, it bounced over that way.

Pupils: Oh. Yeah (some comments and laughter).

Teacher: Okay? So there's another thing we have to... we have to put a limitation on our particle because we can't allow it to go out of the plane either, even though you can force a ball to go out of the plane. So we have to put limitations on our model. But anyways, is there anyone who disagrees with the fact that we can force our particle into behaving like light? (Pause) You will accept that. (Writing on the board, "1. Reflection: 1. small particle, 2. high speed, 3. no energy loss".) So, reflection. In order for reflection, we must have first of all small particles,...high speed... Three things which basically put limits on--we've also put a few other little ones. Yes Tom?

Tom: Um. But, er, when light is, er, a lot of particles of light in there they all bounce the same way. If you have a lot of, er, particles, er, they wouldn't all bounce the same way, would they? They'd collide with each other.

Teacher: All right. They won't all...Would...I'm, I'm going to use this small particle, Tom. I'm

LL.5-7: II-a. This appears to be a description of the demonstration, it therefore constitutes the provision of evidence.

LL.19-23: II-f. A characterization of ID-g for this lesson is inappropriate, for it is clear from the interview that pupils are to be given an alternative model later (p.A66, LL.6-11).

EPISODE 11 (L.36 - p.A54, L.46)

I/II

In this episode, Tom raises the objection that these particles of light will collide. The objection is handled by having Tom state a necessary condition of the particles that will preclude collision. This condition--that particles are to move at the same speed--is then incorporated into the model as one of its features or "limitations. In sum, the teacher treats Tom's suggestion with regard to reason: II-e.

going to bounce them off the desk. Now, as long as the desk is smooth compared to the size of the ball, why won't they bounce in the same direction?

Tom: They'd collide with each other.

Teacher: Do, er...just because the highway's full of cars and they're all going in the same direction and about at the same speed, do they collide with one another?

Tom: No, because you've got them all the same.

Teacher: They're all going the same speed? Tom.

Tom: You can't get them going at the same speed.

Teacher: Why not? In our imagination we can do anything. Okay? So there's another limitation there. If, if they're going to collide if they're different speeds, what do we have to say about the speed of the ball? Not only are they high speeds, but they...?

LL.20-24: I-a, h; II-d. In responding to Tom's argument in this fashion, the teacher provides reasons that are based upon the premise that a model is conceptual.

Pupil: The same speed?

Teacher: Okay, the same speed. So, okay. And you're going to find as you go through any physical model that, because you're using a model, you're going to have to put limitations on that model. The model isn't light. That ball is not light. It's only, we're only using it as a representation of light, and only some of its properties are the same. Now

LL.40-45: I-b, h.

let's get back to try and use our particle model. (A light is placed on the bench.) Now I want you to imagine that this light bulb is a source of light particles. (Switching the light on) Now, if I turn it on. We're...going to get particles, waves... We're going to get particles spreading out here, and we haven't talked about how much light we have. And I would like to just talk about how much light there is there, for a few minutes. And I'm going to do it in maybe a little different way than you might consider. Suppose that I consider a point out in space about here (one foot from the light), and then another point out about here--about twice the distance. What would you say about the amount of light passing through, say, a small region of space--I could imagine a little cross-section...and if I counted all the particles going through that little area out here, and then I move it twice the distance away, how would the number of particles going through that little patch of area compare? Cathy.

Cathy: They would be less in the last one than in the first one?

Teacher: Okay. Can you tell me why? (No response) Jennifer.

Jennifer (quietly): The particles would have had a chance to scatter.

Teacher: Can't hear you.

EPISODE 12 (L.1 - p.A57, L.3).

I/ID

LL.4-7: I-h.

LL.11-12: II-b, since this follows from the statement in LL.4-7.

LL.44-45: II-e. Here it seems that the point made by Cathy is being treated with regard to reason, for Cathy is asked to think of possible causes for what she has said. Yet, as shown in the analysis on p.A56, LL.4-13, it seems that a fully reasoned treatment of the suggestion is not provided.

Jennifer: The particles would have had a chance to scatter.

Teacher: Okay. Maybe, er, the particles run into something else around and scatter. I don't think there is too much scattering. Er, I'll tell you why. Because there doesn't seem to be many dust particles or smoke particles in the air right now. Ken?

LL.4-13: ID-a, b, d. Here, the argument in response to Jennifer's suggestion, which itself is an effort at explaining what Cathy suggested (p.A55, LL.41-43), is incomplete. The idea that smoke particles or dust might have any effect has not been supported.

Ken: I think they would stay the same because, um, you'd get them and they'd go and they plumped off the wall and they would come just back, and so you would still have the same number of particles.

Teacher: All right. What do you say about the number of particles going through a unit area at unit distance from the source?

Ken: I still think it would be the same.

Teacher: They're not going to change. There'd be the same number of particles through each. Okay. Any other suggestions here? Ron.

LL,22-26: II-e. Although there is no immediate reason provided for the acceptability or unacceptability of this suggestion here, it is honored and treated later as with other suggestions, in the following episode. The treatment, or argument pursued then, is quite explicit and complete, p.A57, L.3 - p.A59, L.20. But although it seems that the argu- is absent for the current episode, it seems that the teacher is merely extracting suggestions.

Ron: I think there'd be less because on, er--farther away from the light--because the light, um, the light particles, particles would be absorbed by the air and the dust and the...

Ron introduces the idea that absorption of light particles might occur. Although the idea of absorption has been mentioned previously (p.A49, LL.8-15, the teacher fails to take up this possible explanation on p.A57, L.1: ID-e.

Teacher: How much light? One distance, one distance...

Ron: About half.

Teacher: Half as many. Anybody else? (Pause) Any other guess? Okay. Now let's go back and look at the situation again, okay? Now here's a light bulb and it's putting out approximately the same amount of energy per unit of time-- as time goes on. So, er, if we express this in seconds, the same number of particles should come out of the light bulb per second, and only that number of particles. Now, in what direction are the particles going?

EPISODE 13 (L.3 - p. 59, L.20)

I/II

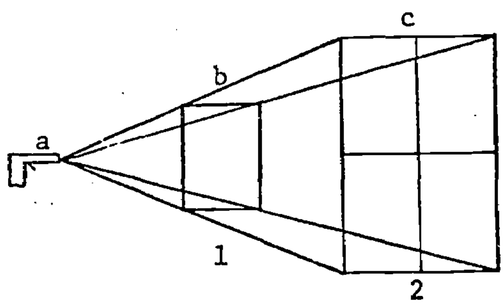
LL.6-10: ID-a. Previously, the situation involved the emission of light particles; the introduction of "energy" is not supported. Further, the claim concerning uniform output over a certain period of time is not substantiated.

Pupil: Every direction.

Teacher: Okay. They're spreading out over the area like this, okay? Bigger, bigger...Now let's just imagine something here. Er, forget about the light bulb for a minute. Suppose, er--I'm going to give you a little example--suppose I have a piece of toast--my hand is the piece of toast --and I want to butter this, okay? And I'm very lazy because I own a restaurant, and I have to butter thousands of pieces of toast every day. So I'm smart...(laughter) and I do things the easiest way possible, so I invent myself a butter-gun (laughter). (He draws parts "a" and "b" of the following diagram.)

LL.19-21: II-e, since an initial condition of this situation was given to be that particles spread out, p.A55, LL.11-12.

In the remainder of this episode, the teacher has pupils determine the numbers of pieces of toast that can be buttered when the "butter-gun" is displaced a certain distance from the first piece of toast. The arguments, then, stem directly from the geometry of the given problem: II-b.



All right, and my butter-gun sprays out butter in a nice, uniform pattern. And it comes out in a nice, uniform pattern. And it comes out in a pyramid shape, er...right here...like here; so that, when I hold the gun a unit distance from one piece of toast, it just covers the toast nicely--just close to the edge, okay? So I hold the toast up here, go "ssst", there's the butter. Now, when I get busy I have to do more toast in the same amount of time. What can I do, Mike?

Mike: Um. Well, hold it back farther.

Teacher: Okay. Now I'm going to, say, hold it back twice the distance. How many pieces of toast can I cover?

LL.20-22: II-e.

Pupil: Two.

Teacher: Two pieces of toast. Can you draw them on the board? (Pause) Can you draw them on the board? Where on the board...where would I put these two pieces of toast at twice the distance, say out here some place, I'm going to have two pieces of toast, right? (Erasing some other writing) I'll have to get rid of this. (Pause)

LL.25-34: II-e. In order for this pupil to prove his point, the two pieces of toast must be seen to correspond to the geometry of the figure.

Pupil: Oh, sir.

Teacher: Put two pieces of toast in front of the gun at distance "2" so that no butter is spilled over the edges--there's no waste of butter.

Pupil: Sir, it's four pieces.

Teacher: Four pieces of toast. Can you put them on the board? (The pupil moves to the board

LL.44-45: II-e.

and draws part "c" of the diagram.) At twice the distance.

Pupil: It looks sort of like this...and we have one over here, and then one beside it, and one below it, and one below this.

Teacher: Okay, you get the idea. All right? Now. Everybody agree with that? Moving out--this is a particle model, we're shooting out particles of butter here--moving out twice the distance, how much area do we cover? Sharon.

Sharon: Four times as much.

LL.19-21: II-b.

Teacher: Four times the area, okay. Now. How much butter has each piece of toast got on it compared to the first piece of toast? Tom.

EPISODE 14 (L.20 - p.A60, L.39)

I/II

Tom: One quarter of the amount?

Teacher: One quarter. How much light is there at twice the distance, Bob?

LL.26-28: II-b. The analogy between light particles and butter has been made previously, LL.12-14, above.

Bob: A quarter.

Teacher: One quarter. If our theory is any good at all, when I measure the amount of light compared at "1" and "2", instead of going to be the same amount of light, instead of going to be half the amount of light, it's going to be a quarter of the amount. Yes?

LL.30-38: II-b. The argument is made by analogy between the particles of butter and the particles of light.

Pupil: But that's, um, assuming that, er, the second space is bigger than the first space. Like if the second space is the same size as the first...

LL.39-44: Apparently, the pupil has not understood the step leading to "one quarter of the amount".

Teacher: No, I said "How much butter per piece of toast?" One piece of toast (pointing to "b"), one piece of toast (a piece in "c"). Four times the amount of butter goes on this piece of toast as compared to that piece of toast. The same area...the same size piece of toast.

LL.1-10: II-b. The argument is reviewed using the diagram on the board.

Pupil: But there's four toasts over there.

Teacher: Right. And look at ...if I draw the same kind of triangle out from the light, I can put in, fit in four of my unit areas over here, couldn't I?

LL.13-18: II-d.

Pupil: Yeah. But the area that the butter covers on the first toast is smaller than the area that the butter has to cover over there. So if you just put one toast out on side "2", it would, er, still be the same amount covered, wouldn't it? Because, no, over there you've got four pieces of toast to be covered. It's four times the amount that has to be covered in the first one. So you've got to use, um...so you've obviously have less...less butter on it.

LL.19-34: II-e. The teacher seems to permit the pupil to extricate himself from the difficulty. This leads the pupil to make the argument that the teacher has previously advanced.

Teacher: Right. That's the point that we're after. There is less bu ter. There is light over here, because it's spread over more volume. Now, if we did a rigorous mathematical description of this we'd have to describe all of the space, not just a cone of space. But I think you can see that if I draw a ball around the light bulb here (close to the light bulb) the surface of the ball is much smaller than

LL.35-39: II-b, d, since the argument has been presented previously in Episode 13.

EPISODE 15 (L.39 - p.A61, L.33)

I/II

LL.39-44: II-a. Support is provided for this assertion in the demonstration that follows.

L.44-p.A61, L.6: II-b.

the surface of the ball here, as compared to a ball out here (further from the light bulb)--here we've got a great big ball (some laughter). Now, the same amount of light per unit of time has to spread over the inside surface of that ball no matter where it is. So that if I have a little wee ball (closing his hands over the light bulb)--you just look in there, there's a lot of light on my hands. If I move it out, there's not nearly as much light on my hands. Now look, there's only one way to check this, of course. Theory says that for the amount of light, (writing on the board, "2. Amount of light, 2d $\rightarrow$ 1/4 amount") with particles twice the distance...we should get one quarter the amount of light. Now. Of course, if we don't get one quarter the amount of light, we're going to have to throw our particle model out and start all over again because it'll be no good. Anyways, here's the unit area--I'm going to call it a unit area. This is a solar cell, it measures the amount of light--you'll have to accept that, we can talk about it later on--but it measures the amount of light. And when, the way it measures it is simply converts all the light that gets into it into electricity. So I'm going to measure the amount of light in terms of electricity. I happen to have a meter which is sensitive enough to do this. It doesn't generate very much light, but it does generate...or, sorry, very much electricity

LL.6-10: ID-a. This fundamental assumption of the argument was asserted earlier, p.A57, LL.6-10 and, at that time, was not supported by evidence.

LL.10-18: II-a.

LL.20-33: I-h; II-b, this judgment made because the grounds upon which the model is to be judged are provided.

EPISODE 16 (L.34 - p.A63, L.12)

I/ID

LL.36-42: ID-a. In having to accept the truth of this assertion, pupils become intellectually dependent upon the teacher.

LL.42-46: ID-a. The use of this solar cell and its response to variation in light intensity become a crucial part of the argument that follows. Without some independent support for the meaning of meter readings, the argument is incomplete: ID-b.

but it does generate some. And, er, what I'm going to do is try and find the spot which will put this... (adjusting the separation between the solar cell and the light bulb)...Okay. I should actually move my light back to here so I can measure it a little better. And here, at about ...(using a meter rule)... er, somewhere around seventeen centimeters I get a full-scale deflection...I think that probably everyone can see that. (The needle points to "2" on the scale.) Can everyone see?

Pupil: Yeh.

Teacher: You can see, I take it. So somewhere around seventeen centimeters I get almost a full-scale deflection. If our theory is right, at thirty-four centimeters how much current should I get?

Pupil: One?

Pupil: Half.

Teacher: A quarter of two is one (laughter) What is it? A half, okay. We'll just accept those units on there, so--where was I? I'm going to turn my ruler over because it's easier to read...(indistinct) What did I say before, seventeen centimeters? We'll just check that. Seventeen. And I'll go out to thirty-four, and...low and behold, it's just around zero five, er point five (the needle is at ".65" on the scale). So up here at...we've got two at thirty-four we've got around .5--maybe a

LL.2-11: This portion is procedural since it contains description of what is being done by the teacher.

LL.22-25: II-a.

LL.31-33: II-d. The prediction made here derives from the conclusion of the "butter-gun" argument, p.A59, LL.30-38.

L.44-p.A63, L.1: ID-h. There is a discrepancy between the predicted reading and the obtained reading. Furthermore, on p.A63, LL.1-5, the explanation offered is not complete as an argument, for no support has been provided for assertions about

little bit over. Er, we could explain the difference I suppose in terms of the characteristics of the meter. But you see it's definitely not a half, it's much less than 1. Our theory tells us that the quantity of light at twice the distance is a quarter the amount. We've got a good theory. Okay.

(The lesson ends.)

the characteristics of the meter used.

LL.1-5: ID-g. This discrepancy can also be accounted for by the uniform light in the classroom.

LL.7-12: ID-f. Pupils are not permitted to judge the significance of the discrepancy, so they are unable to judge the adequacy of the particle model.

TRANSCRIBED INTERVIEW FOR

"A PARTICLE MODEL OF LIGHT"

(The interview begins.)

The teacher is describing the class as the tape recorder is switched on.

Teacher: The, er, that class there is...actually, this has some of the slower of all the nines that we have this year--just comparing the nines that we have. We have four classes of nines. Er, the class that just came in now has a much higher percentage of good people. There are... there are about four or five people in the class that you just saw who, er, probably shouldn't be in this particular program because some of the ideas are a little bit heavy for them, you know. So that--especially with the microphone there--they were really keeping quiet, those people. Usually those people are the ones that we will, in a lesson like that-- well, as I say, we don't normally do it that way. I would normally do it more in groups of five. You know, that way was more of a demonstration lesson. I would say take five and do the same type of thing only develop them with three or five people while the rest of the class went on and did another experiment.

Interviewer: Oh, I see.

T: So I find it, it's better...you see, what I don't like about that lesson--just my own point of view is--I really only talk to four or five people in that class. You know, there are four or five that were a little better and there were a couple that were a little extra better than the rest of them. That's one of the reasons that they were shy, because I usually don't insist on the formality of a teacher at the front, a student there. We don't have that kind of relationship normally. We usually sit around the desk and we do it together more or less. So that may be a part of what was happening at the first there. But they, they ...you know, I figured they did...they did come a little bit at the end there.

I: Right.

T: But anyway, shoot your questions, then we'll...

I: Yes. To start off with they'd obviously done quite a few experiments with reflection. I wondered if you could give me an idea of what experiments they have done. What phenomena, in other words, have they...

T: Er. Well we, we just started off, er, with light by just, er, bringing out a light source. You know we use, well they're not here, just a little box with the light in it. And the first thing we did was to, er, punch two holes in the end of a shoe box and one in the top, and you look through the end of the shoe box and you see the light, and you look down in the shoe box and you don't see the light. So we worked around that. Now that's a very simple thing, but we eventually decided if we filled

the box up full of smoke or chalk dust or something like that we might be able to see it. So we did that and, of course, we could see it through, er, scattering. So, er, we got the idea, then, in order to see the light it has to bounce off something. So that was the first step. The second step was that we, we just threw a mirror at them and we did, er, inversion. First of all, you know, we, you have the students stand up and, er, look in the mirror. And then you say "Where's your left ear?" and he puts a piece of tape where his left ear is. And then you have him turned around and, er, look the same way he was in the mirror. So, this was his left ear at one time, at that was his left ear the other time. Now his left ear's on his right side, and, er, you know, when you word it that way, then that gives him a problem. There's no problem at all, it's just that you've tricked them into believing there is a problem and then they've got to think about how to get out of it. And then we do it with words, too--like "tom" turns into "mot" you know. And then that gets them thinking about the laws. And then yesterday we did the pins--and that's why they, they still don't know the laws because we just, sort of, did them, er, yesterday--and, er, showed them that, you know, for regular reflection you got angles. And that's as far as we were. And then I wanted to introduce the particle theory which is really what is going to be introduced in the next experiment by the questioning in the experiment itself. So, the normal way of developing the particle theory would have been through...Now see, what we...what we're going to do is thoroughly convince them that the particle theory is right, and then I'm going to do refraction. And that's it, you see. Now they're going to...that's... it's wrong, so we're going to start all over again. And it works out very nicely when you, er, as I say, you get more arguments, er, people thinking a little better in the other classes. But, er, you get this, a couple of good people in that class. And I think it's...the rest of them follow along enough, then it's worthwhile...

I: Yes.

T: ...doing that stuff.

I: Models were mentioned during most of the lesson...

T: That's what the whole thing was...

I: Yeah, right. What do they understand by a model?

T: Well, this is a continuing sort of concept. They, er...we haven't, we're just this time round going in...I've stayed away from the idea that a model is really a mathematical model because mathematics, to them, is a bad word, and I would, you know...well we didn't do a rigorous development of Inverse Square and I never mentioned Inverse Square--and I won't mention Inverse Square. Because, if they go on and they do it in grade eleven, they'll get enough mathematics for it. I only want the idea that the model predicts something, and that something's all right, so the model's good; we can go back and use the model again and get something else out of it. Or, we can come across a phenomenon, light, and go back to the model and say "Does the model agree with this?" So that right now they have a rather weak idea of what a model is. That, they...they just think it's an idea, er, that, you know...well we developed, er,

essentially the Kinetic Theory of Heat without really ever mentioning that it was the Kinetic Theory of Heat until right, right at the end and then I put the word "kinetic" on the...we didn't do any of the math, of course. Er, but we...they're, they're, um,...they've been working with particles all along. And we started out with the atom, so they have some idea, er, particle model of matter. But it's still very vague, and after this section's over I think we'll...when we do the particle model of light and the wave model of light and then they've two very good models--two strong models--that they can compare, they can see some weaknesses in one and strong points of others, and by that time we should have an idea of what a model is. But we're still working on that idea, it's sort of a thing we just sort of come back to once in a while in the course.

I: The speed of light came up and I wondered, and I--just from the answers to the question a few questions ago--that they hadn't done much on light. So am I right in presuming they haven't done anything on the speed of light before?

T: No they haven't. No.

I: This is a new thing to them, it's quite a startling thing to them, I guess. They were trying to figure that out...

T: Yeh. Yeh, well we were...

I: ..."How long do you wait when you switch the light on to get light?"

T: Yeh, yeh. We'll come back to that, er, I intend to come back to that because there's a lot of fascinating things there, er, just in...in the speed. Er, well when...when we talk about refraction, of course, when we get in we'll talk a little bit about speeds there. Er, that's when I come back to that point, I hope. I never know what's going to happen from one day...I don't really...I don't have a rigorous plan of actions. The, er,...I wasn't sure last night that I was going to, er, do, er, Inverse Square Law. I, sort of, picked a number of other things--heat, I was...But I, er, hooked up the apparatus last night and that one seemed to work the best, you know, easy results--easy numbers like two, a half--things like that. Rather than the heat because the heat, with the temperature--with the thermometer--they couldn't see it; so, whereas I might have done heat if I'd been doing it at individual desks, you know. And quite often what I will do is do one with one group and one with another group. So, I'll give one half of the class part of the information, and the other half of the class part of the information. I have--I don't think I'll do it this year because we're getting a little late in the year--but, I have developed...fairly convinced one half of the class that the particle model's right, and at the same time have the other class...I just said, "Well, we haven't got enough equipment" which wasn't true, but...one half was working on ripple tanks, one half was working on the particles...and of, from their experiments with the pins and the rest of it. And, er, one half was fairly convinced that particle was right, the other half was fairly convinced that the wave model was. Then I turn them loose and it was a beautiful class...just beautiful they

were going at one another's throat. I haven't had time to do that this particular year. The class isn't quite strong enough. But there's a lot you can do at this level as long as, er...one of the first sort of things we do in the course, which I look on as part of a test, is we develop the size of a molecule. You know the thin layer experiment, you know that one...

I: Yes.

T: ...the mono-layer experiment? We do that, and we do the math. And, er, if we get a really strong negative reaction to the math, then that's the last time we ever deal with any other math, most any. If we get an easy reaction to the math, then we go on and develop it a little. Some, I've had three years of the course, out of about nine classes I've had one class that could do more math so I used to feed a little bit in, like Inverse Square Law I'd finish up or else I'd do it the next day. I'd actually do the Inverse Square Law. And they really ate it up, but there were only nineteen or twenty-one students and they were all good. They were, they were...that was, the days when we split the classes up, er, 9A was the top class and 9D was the poor class, and now they're on integration so you can't do it.

I: Um. When you were bouncing the ball at one time, you were bouncing the ball vertically on the desk and you asked Jennifer to note where the height of the bounce, and energy came up as an explanation of what was happening. There was loss of energy. Presumably, they're familiar with the word "energy"...

T: Yeh, they are...

I: ...what sort of things have they done with it?

T: Er, well we, we did a little bit of kinematics--just a very little bit, where we did, er, you know, er, Newton's First and Second Law, and, er, we talk...it was, the energy that they have...the idea of energy that they have is still pretty vague, so, um, I tried to get around that point, I suppose, rather than, er, really go into it because their ideas of energy are still a little bit vague. We haven't really done too much on it. But he did mention the fact that the ball had to have bounce and, er, I thought I might as well mention it because he was on the right track or something. He, er...I was surprised that he would think of that really. Er, that's one of the things that I don't think I've come across in a grade nine class--that they consider. I think he had the idea there ...he had the bounce...the right amount, er it's been working. I wasn't prepared for it to tell you the truth--I hadn't had that response before, it caught me on a short foot so I had to, er, wiggle around a little bit.

I: I'm very curious still about their understanding of "model".

T: Ahm. Well, what we, what we did in model...we started off with the, er...with, with just the classical idea that if you take a piece of matter and you start cutting it up, were, were there any limits to this and what were the limits to it. And, er, we got into, um, you know, the

molecular model and we sorted out the difference between molecules and atoms. And then we went into the model of an atom, Rutherford and Bohr model--Bohr concept of an atom--without getting into any idea that it's really connected with mass. So, er, er, I would say that as far as their concept of model, they're about half-way to where we want them to be at the end of the year. By the end of the year we like to have them understand that a model is basically an idea, it's basically a mathematical thing and not a physical thing, even though the physical models...See, we've shown them physical models like the, you know, the molecule and that sort of thing. So their idea of a model right now is still somewhat physical. It's a solid thing, you know, and you do experiments with it, and that's it. So that, er, this is sort of a transition stage. We'll get into the wave model and that's more mathematical than anything we've had so far, so it'll, you know that's...hopefully will put it all together before, you know, the end of the year. There are a lot of loose ends in the course which we shall try and fit together at the end. We don't get them all, I suppose...it's, er...The, the part of the course, er, no,... is really, a lot of it is skill, er, lab. where we're really, we just, we use a lot of equipment and we get them used to doing labs., doing stuff at their desks independently so they don't become, er, dependent on the teacher. The main thing, of course, is that, er, when they get into ten, if they take the science, they'll be doing this Biology Green Version and they need a lot of the basic measurement techniques. So, the whole course is really based around measurement techniques. And then from now on we'll start asking them questions like, er, "Design an experiment, how would you do this?" Up till this, up till about a month ago we were really just exposing them to equipment, you know, getting vocabulary down and this sort of thing...

I: Right.

T: ...doing it the easy way. I like to think that the more you use it, then you eventually accept it. Like the metric system, they can all work in, er, centimeters and meters and milliliters and cubic centimeters. Never had a formal lesson on it because all I did was give them...I've got a set of half-meter sticks which only have centimeters on them, you know, and every time they want to measure that's what they get. So, er, it, you know, "Here's a meter ruler, well measure" but, er...

I: Thank you very much.

T: Oh, you're welcome.

I: That's really tremendous. The class was very enjoyable and you've certainly given me a tremendous amount of information here--talking on and answering the questions.

T: Well, it will keep you busy for a while (laughter).

(The interview ends.)